AD-A286 892

Defense Nuclear Agency
Alexandria, VA 22310-3398

DNA-TR-93-173-V2

The Effect of MOPP4 on M198 Howitzer Crew Performance
Volume 2—Task Times for Fire Missions

Gene E. McClellan
Leigh N. Matheson
George H. Anno
Pacific-Sierra Research Corp.
2901 28th Street
Santa Monica, CA 90405-2938

Arthur P. Deverill, Jr.
Anthony J. Barkely
ARES Corp
1800 North Kent Street
Suite 1230
Arlington, VA 22209

May 1996

Technical Report

CONTRACT No. DNA 001-90-C-0164

Approved for public release;
distribution is unlimited.

96-01707

Destroy this report when it is no longer needed. Do not return to sender.

PLEASE NOTIFY THE DEFENSE NUCLEAR AGENCY, ATTN: CSTI, 6801 TELEGRAPH ROAD, ALEXANDRIA, VA 22310-3398, IF YOUR ADDRESS IS INCORRECT, IF YOU WISH IT DELETED FROM THE DISTRIBUTION LIST, OR IF THE ADDRESSEE IS NO LONGER EMPLOYED BY YOUR ORGANIZATION.

DISTRIBUTION LIST UPDATE

This mailer is provided to enable DNA to maintain current distribution lists for reports. (We would appreciate your providing the requested information.)

☐ Add the individual listed to your distribution list.

☐ Delete the cited organization/individual.

☐ Change of address.

NOTE:
Please return the mailing label from the document so that any additions, changes, corrections or deletions can be made easily. For distribution cancellation or more information call DNA/IMAS (703) 325-1036.

NAME: ____________________

ORGANIZATION: ____________________

OLD ADDRESS	**CURRENT ADDRESS**

TELEPHONE NUMBER: ( ) ____________________

DNA PUBLICATION NUMBER/TITLE	**CHANGES/DELETIONS/ADDITIONS, etc.)** *(Attach Sheet if more Space is Required)*

DNA OR OTHER GOVERNMENT CONTRACT NUMBER: ____________________

CERTIFICATION OF NEED-TO-KNOW BY GOVERNMENT SPONSOR (if other than DNA):

SPONSORING ORGANIZATION: ____________________

CONTRACTING OFFICER OR REPRESENTATIVE: ____________________

SIGNATURE: ____________________

CUT HERE AND RETURN

DEFENSE NUCLEAR AGENCY
ATTN: IMAS
6801 TELEGRAPH ROAD
ALEXANDRIA, VA 22310-3398

DEFENSE NUCLEAR AGENCY
ATTN: IMAS
6801 TELEGRAPH ROAD
ALEXANDRIA, VA 22310-3398

REPORT DOCUMENTATION PAGE	Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	960501	Technical 930301 – 950615

4. TITLE AND SUBTITLE
The Effect of MOPP4 on M198 Howitzer Crew Performance
Volume 2—Task Times for Fire Missions

5. FUNDING NUMBERS
C - DNA 001-90-C-0164
PE - N/A
PR - RM
TA - RH
WU - DH303390

6. AUTHOR(S)
Gene E. McClellan, Leigh N. Matheson and George H. Anno (PSR)
Arthur P. Deverill, Jr. and Anthony J. Barkely (ARES)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Pacific-Sierra Research Corp.
2901 28th Street
Santa Monica, CA 90405-2938

ARES Corp
1800 North Kent Street
Suite 1230
Arlington, VA 22209

8. PERFORMING ORGANIZATION REPORT NUMBER
PSR Report 2492

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Defense Nuclear Agency
6801 Telegraph Road
Alexandria, VA 22310-3398
RAEM/Kehlet

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
DNA-TR-93-173-V2

11. SUPPLEMENTARY NOTES
This work was sponsored by the Defense Nuclear Agency under RDT&E RMC Code B4662D RM RH 00038 STRP 3500A 25904D.

12a. DISTRIBUTION/AVAILABILITY STATEMENT	12b. DISTRIBUTION CODE
Approved for public release; distribution is unlimited.	

13. ABSTRACT (Maximum 200 words)
This work represents field measurements of task completion times for the crew of an M198 Howitzer. The M198 is a towed, 155mm artillery piece, manned by a 10-member US Marine crew for the exercise. Baseline times in battle dress uniform and degraded times in full nuclear and chemical protective gear (MOPP4) are included. Times are reported for 22 tasks composing a fire mission. Task performance is defined as the ratio of baseline task completion time to completion time with crewmembers in MOPP4. A regression of performance versus time in MOPP4 separates the performance degradation caused by the encumbrance of the MOPP gear from that caused by accumulating heat strain. Meteorological data and physiological data from the exercise are included in the report.
12 of 22 M198 tasks show significant degradation from encumbrance effects. 10 of 22 tasks show significant degradation with time in MOPP4. Degradation is correlated with demand ratings on human abilities of the tasks and with the number of crewmembers involved in a task. The measurements and analyses are part of an ongoing effort of DNA's NBC Consequence Assessment Program to support quantification of military performance degradation in an NBC environment.

14. SUBJECT TERMS

MOPP	Task Times	Crew Performance
Howitzer	Heat Strain	Field Measurements
Fire Mission	Encumbrance	Performance Degradation

15. NUMBER OF PAGES 432

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR

NSN 7540-280-5500

Standard Form 298 (Rev.2-89)
Prescribed by ANSI Sts. 239-18
298-102

CLASSIFIED BY:

N/A since Unclassified.

DECLASSIFY ON:

N/A since Unclassified.

SUMMARY

This report, *The Effect of MOPP4 on M198 Howitzer Crew Performance*, in three volumes presents and analyzes field measurements of task completion times for the crew of a towed, 155 mm howitzer with crewmembers in Battle Dress Uniform (BDU) and Mission-Oriented Protective Posture, Level 4 (MOPP4). This volume of the report focuses on tasks performed by an individual crewmember or a subgroup of crewmembers during fire missions. Task times for crewmembers in BDU are used as baseline values to calculate performance degradation caused by MOPP4. The performance in MOPP4 is analyzed for both an early, encumbrance effect and performance decreasing with time in MOPP4.

Section 4 of this volume describes the fire mission tasks for each M198 crewmember and the procedure for calculating task completion times from the field-measured event times. These descriptions with event timelines, displayed mission-by-mission in Appendix A, provide a comprehensive picture of M198 crew operations during a fire mission.

Fire mission scenarios in MOPP4 were conducted with standard crew positions on some days and on other days with rotating crew positions to reduce heat strain by distribution of metabolic work load among crewmembers. The results for these two types of scenarios, denoted in this report by MOPP4-S and MOPP4-R, respectively, are presented separately to facilitate future comparison of the operational effectiveness of the two procedures. Daily mission lengths, determined by crew attrition from heat strain, should provide an easy comparison of MOPP4-S and MOPP4-R. However, according to the analysis in Section 5, day-to-day variations in meteorology explain a substantial part of the variation in daily mission length. A definitive analysis of relative effectiveness of the MOPP4-S and MOPP4-R procedures would require time-dependent modeling of ambient meteorological conditions and metabolic work rate of the crew.

Using all MOPP4 data, 12 of 22 M198 tasks show significant encumbrance degradation when judged by performance on the first fire mission of each day. Regression analysis of performance versus time in MOPP4 shows that performance degradation increases with time in MOPP4 for 10 of 22 tasks.

Performance degradation in MOPP4 is analyzed by placing the M198 tasks in four groups (Section 7) according to whether a task shows encumbrance degradation and whether it shows increasing degradation with time in MOPP4. Examination of the nature of the M198 tasks in each group leads to the following conclusions:

1. M198 tasks performed by a single crewmember with no potential for interruption (delay) by another task are least likely to show performance degradation from MOPP4.

2. M198 tasks that involve more than one crewmember are more likely to show encumbrance degradation than tasks performed by a single crewmember.

3. For M198 tasks, the likelihood of increasing degradation with time in MOPP4 is not sensitive to the number of crewmembers involved.

4. The M198 tasks for which performance degrades with increasing time in MOPP4 tend to have higher physical demand and lower cognitive demand than tasks that have little or no increase in degradation.

The richness of the data set gathered and compiled during this effort enables fu 'her analyses. Possibilities are described in the concluding section of this volume.

PREFACE

This report was prepared for the Radiation Risk/Safety Program at the U. S. Defense Nuclear Agency (DNA). DNA's technical monitors for this project were Mr. Robert A. Kehlet and Dr. Robert W. Young of the Environments and Modeling Division. The analysis in this volume of the report was supported by ARES Corporation with funding from DNA through Contract DNA 001-90-C-0164. Pacific-Sierra Research Corporation (PSR) participated with funding from the same contract through subcontract ARES-PSR-90-C-001.

Data were collected by DNA researchers from ARES, EAI Corporation, and PSR on a noninterference basis during a four-week exercise conducted in August of 1992 by the U.S. Army Human Engineering Laboratory (HEL) at Aberdeen Proving Ground. The exercise, *Assessment of Towed Artillery (M198) Crew Performance in NBC Protective Clothing*, was directed by Mr. Orest Zubal of HEL whose cooperation is gratefully acknowledged. The exercise was funded by the P^2NBC^2 Project Office of the U. S. Army, the acronym standing for *Psychological and Physiological Effects of the NBC Environment and Sustained Operations on Systems in Combat.* Mr. Kehlet of DNA and Mr. Don Cunningham, P^2NBC^2 Program Manager, U. S. Army Chemical School, were instrumental in arranging on short notice for the DNA research team to take advantage of this important data collection opportunity.

Volume 1 of this report provides an analysis of the MOPP4-induced performance degradation of aggregate crew activities, specifically, emplacement and displacement times and rates of fire. Volume 3 provides a comparison of field-measured, crewmember performance degradation with estimates of performance degradation obtained from the same crewmembers with a questionnaire.

CONVERSION TABLE

Conversion factors for U.S. Customary to metric (SI) units of measurement

MULTIPLY → / TO GET ←	BY → / BY ←	TO GET → / DIVIDE ←
angstrom	1.000 000 X E -10	meters (m)
atmosphere (normal)	1.013 25 X E +2	kilo pascal (kPa)
bar	1.000 000 X E +2	kilo pascal (kPa)
barn	1.000 000 X E -28	meter^2 (m^2)
British thermal unit (thermochemical)	1.054 350 X E +3	joule (J)
calorie (thermochemical)	4.184 000	joule (J)
cal (thermochemical)/cm^2	4.184 000 X E -2	mega joule/m^2 (MJ/m^2)
curie	3.700 000 X E +1	*giga becquerel (GBq)
degree (angle)	1.745 329 X E -2	radian (rad)
degree Fahrenheit	$t_K = (t°f + 459.67)/1.8$	degree kelvin (K)
electron volt	1.602 19 X E -19	joule (J)
erg	1.000 000 X E -7	joule (J)
erg/second	1.000 000 X E -7	watt (W)
foot	3.048 000 X E -1	meter (m)
foot-pound-force	1.355 818	joule (J)
gallon (U.S. liquid)	3.785 412 X E -3	meter^3 (m^3)
inch	2.540 000 X E -2	meter (m)
jerk	1.000 000 X E +9	joule (J)
joule/kilogram (J/kg) (radiation dose absorbed)	1.000 000	Gray (Gy)
kilotons	4.183	terajoules
kip (1000 lbf)	4.448 222 X E +3	newton (N)
kip/inch^2 (ksi)	6.894 757 X E +3	kilo pascal (kPa)
ktap	1.000 000 X E +2	newton-second/m^2 (N-s/m^2)
micron	1.000 000 X E -6	meter (m)
mil	2.540 000 X E -5	meter (m)
mile (international)	1.609 344 X E +3	meter (m)
ounce	2.834 952 X E -2	kilogram (kg)
pound-force (lbs avoirdupois)	4.448 222	newton (N)
pound-force inch	1.129 848 X E -1	newton-meter (N·m)
pound-force/inch	1.751 268 X E +2	newton/meter (N/m)
pound-force/foot^2	4.788 026 X E -2	kilo pascal (kPa)
pound-force/inch^2 (psi)	6.894 757	kilo pascal (kPa)
pound-mass (lbm avoirdupois)	4.535 924 X E -1	kilogram (kg)
pound-mass-foot^2 (moment of inertia)	4.214 011 X E -2	kilogram-meter^2 (kg·m^2)
pound-mass/foot^3	1.601 846 X E +1	kilogram/meter^3 (kg/m^3)
rad (radiation dose absorbed)	1.000 000 X E -2	**Gray (Gy)
roentgen	2.579 760 X E -4	coulomb/kilogram (C/kg)
shake	1.000 000 X E -8	second (s)
slug	1.459 390 X E +1	kilogram (kg)
torr (mm Hg, 0° C)	1.333 22 X E -1	kilo pascal (kPa)

*The becquerel (Bq) is the SI unit of radioactivity; 1 Bq = 1 event/s
**The Gray (Gy) is the SI unit of absorbed radiation

A more complete listing of conversions may be found in "Metric Practice Guide E 380-74," American Society for Testing and Materials

TABLE OF CONTENTS

TABLE OF CONTENTS

FIGURES

FIGURES (Continued)

Figure | Page

FIGURES (Continued)

FIGURES (Continued)

Figure | Page

FIGURES (Continued)

Figure | Page

FIGURES (Continued)

Figure Page

FIGURES (Continued)

FIGURES (Continued)

TABLES

TABLES (Continued)

Table		Page

SECTION 1
INTRODUCTION

During August of 1992, a team of contractors sponsored by the Defense Nuclear Agency (DNA) participated in an artillery field exercise at Aberdeen Proving Ground under the U. S. Army's P^2NBC^2 program. The purpose of the exercise was to measure and contrast various task completion times of an M198 howitzer crew in battle dress uniform (BDU) and in full nuclear and chemical protective gear (Mission-Oriented Protective Posture, Level 4 or MOPP4). The DNA team, on a noninterference basis, recorded time and motion data for the exercise. Volume 1 presents data on howitzer emplacement and displacement times and data on fire mission times aggregated to the level of time to first round and time between rounds. This report (Volume 2) provides detailed results for 20 crew tasks composing a fire mission.

For easy reference, basic descriptive data for the exercise from Volume 1 is repeated in this introduction.

1.1. DESCRIPTION OF THE M198 HOWITZER CREW.

The M198 howitzer is a towed, 155 mm weapon and was manned by a ten-member U. S. Marine crew for this exercise. The crew consisted of a Chief of Section, a Gunner, an Assistant Gunner, a Radio Telephone Operator (or Recorder), and six Cannoneers. The six Cannoneers are the loader (No. 1 Cannoneer), three projectile handlers, and two powder men. Table 1-1 summarizes the main tasks of the crew during a fire mission.

Table 1-1. Brief task descriptions for the crew of the M198 (155 mm) howitzer during fire missions.

Crew Member(s)	*Task Descriptions*
Chief of Section	Receive fire order and call projectile, charge, fuze, deflection and quadrant elevation (QE).
Gunner	Set deflection on sight, traverse tube/level bubble, check sight picture and level bubbles.
Assistant Gunner	Set QE on range quadrant and elevate tube/level bubbles.
Cannoneers	Load projectile and propellant. Close breech and prime firing mechanism. Attach lanyard. Open breech, swab and inspect bore.

Selection of event times to be recorded was based primarily on the major task groups as represented in Table 1-1 and secondarily on readily discernible aural or visual cues for the human observers. A team of observers collected data in real time using notebook computers and appropriate software as described in Section 2 of this report. These events are used to calculate task times as described in Section 3. Table 1-2 outlines the recorded time points for each fire mission.

Table 1-2. Fire mission events recorded for the M198 howitzer including schematic timelines.

Event	† = *Time Recording Points*
CHIEF OF SECTION	
Receive/call out fire mission	† — †
Standby	†
GUNNER	
Set deflection on sight*	† —
Traverse tube/level bubble	† — †
Check sight picture	† — †
ASSISTANT GUNNER	
Set QE on range quadrant*	† —
Elevate tube/level bubbles	† — †
Depress tube for loading	† — †
CANNONEERS	
Load start (set tray)	†
Ram projectile	†
Close breech; prime	† — †
Fire	†
Open breech/swab bore	† — †
RANGE SAFETY OFFICER	
Safety check	† — †

*The end of this task is marked by the beginning of the subsequent event.

1.2. DESCRIPTION OF THE M198 HOWITZER EXERCISE.

Three M198 howitzer crews spent two weeks each in this exercise. After a week of preparation and training, each crew conducted a series of fire missions for the record on Monday, Wednesday, and Friday of their second week. A day's planned exercise included 17 fire missions with a total of 89 inert rounds to be fired. Table 1-3 presents the three mission scenarios used by the crews. The three scenarios are similar, consisting of the same 17 fire missions with minor variations in order. Each scenario begins with 7 fire missions totaling 30 rounds followed by a road march for resupply. Five of these first missions are *normal*, that is, the elevation angle is low enough that the barrel need not be depressed between rounds for reload. The other two fire missions are *high angle*, requiring the barrel to be depressed for reload.

After resupply, each scenario has 10 fire missions totaling 59 rounds. Nine of these are normal fire missions, ranging from 3 to 5 rounds each. The other fire mission is a *zone and sweep* mission consisting of 25 rounds. The aim point for each round of the zone and sweep is shifted to generate a 5-by-5 grid pattern for the laydown. The zone and sweep fire mission is the most demanding as far as sustained effort is concerned.

Table 1-4 presents the schedule of scenarios followed by each crew and the outcome for each scenario. In battle dress uniform (BDU), all three crews completed the scenarios as planned. Crew 1 repeated its BDU exercise on Friday (with a different scenario) because of technical difficulties with instrumentation on the howitzer on Monday, the first day of the exercise. Since the DNA team also made adjustments in its data taking procedures following the first day's experience, this report does not analyze the first day's data for Crew 1.

On one day for each crew, all operations were conducted in MOPP4 with standard crew positions and standard adjustments for loss of crew members (MOPP4-S). Crews 2 and 3 also conducted a day of operations in MOPP4 with an experimental, regimented rotation of crew positions designed to distribute the thermal-related work load more evenly across crew members (MOPP4-R). In addition to changing positions for the regimented rotation, one crew member was rotated into the shade for rest after each fire mission.

As part of the safety conditions of the exercise, medical personnel monitored the core temperature, heart rate, and skin temperature of each crew member while in MOPP4 to limit the amount of heat stress to be suffered by each. The first limitation was that a crew member's core body temperature should not rise above 39.4 degrees Centigrade. In addition, a crew member's heart rate should not exceed 160 beats per minute for more than five minutes at rest nor should it exceed 180 for more than five minutes at work. If any of these physiological conditions were exceeded by a crew member, he was withdrawn from operations and given medical attention. The remaining crew members then resumed operations with position and task adjustments as necessary. When only six crew members remained, the exercise was halted.

Table 1-3. Daily mission scenarios showing number of rounds planned for each fire mission.

Fire Mission Number	*Number of Rounds (Alternate Mission Scenarios)*		
	A	B	C
1	6	6	6
2	5 HA[1]	4	5 HA
3	4	5 HA	4
4	4	4	5 HA
5	5 HA	5 HA	4
6	3	3	3
7	3	3	3
Resupply and road march			
8	4	4	4
9	3	25 ZS[2]	3
10	25 ZS	3	5
11	5	5	25 ZS
12	5	5	3
13	3	3	3
14	3	5	5
15	5	3	3
16	3	3	3
17	3	3	5

[1]HA = High angle (elevation greater than 1000 mils)

[2]ZS = Zone and sweep

Table 1-4. Summary of daily scenarios for the P^2NBC^2 M198 howitzer exercise.

Date (1992)	*Crew*	*Weekday*	*Mission Scenario*	*Posture*[1]	*Scenario Completed*	*Fire Missions Completed*	*Rounds Fired*
10 Aug	1	Monday	A	BDU	Yes	17	89
12 Aug	1	Wednesday	C	MOPP4-S	No	7	30
14 Aug	1	Friday	B	BDU	Yes	17	89
17 Aug	2	Monday	A	BDU	Yes	16[2]	89
19 Aug	2	Wednesday	B	MOPP4-S	No	6	27
21 Aug	2	Friday	C	MOPP4-R	Yes	17	89
24 Aug	3	Monday	B	MOPP4-S	No	8+	42[3]
26 Aug	3	Wednesday	A	BDU	Yes	17	89
28 Aug	3	Friday	C	MOPP4-R	No	9	37
					Totals	114+	581

[1] BDU = Battle dress uniform
MOPP4 = Mission-Oriented Protective Posture, Level 4
-S = Standard positions with adjustments for missing crew members
-R = Regimented rotation of crew positions to distribute thermal work load

[2] On this day, rounds from Fire Mission 17 were included in Fire Mission 16 to meet a time deadline for cessation of firing.

[3] On Monday, Crew 3 operations were halted after partial completion of fire mission 9 (8 of 25 rounds fired).

For all three crews, the first scenario followed in MOPP4 was with standard crew positions (MOPP4-S). None of the crews was able to complete its scenario. Each crew completed 6, 7, or 8 fire missions before medical personnel pulled the fourth crewmember, halting the exercise. Crew 3 fired the most rounds, partially completing its zone and sweep fire mission in Scenario B.

Crews 2 and 3 followed a scenario in MOPP4 with regimented rotation (MOPP4-R). The members of Crew 2 paced themselves well and were able to complete all 17 fire missions, although only 7 crewmembers remained for the later fire missions. Crew 3, on the other hand,

completed only 9 fire missions, fewer than for its MOPP4-S scenario.

Table 1-5 presents the mission start, stop, elapsed times, and reason for termination. As procedures became routine, there was a general trend toward earlier start times. On only one day did operations halt before noon Eastern Daylight Time (EDT).

Table 1-5. Start, stop and total times for each day of the M198 howitzer exercise.

Day[1]	*Mission Start*[2]	*Last Round*	*Mission End*	*Reason for Termination*	*Total Elapsed Time*
C1M	10.6272	15.9125	16.2561	Normal	5.629 = 5h 38m
C1W	10.2944	12.3767	13.20	Medical	2.906 = 2h 54m
C1F	9.6672	13.5925	13.7772	Normal	4.11 = 4h 7m
C2M	10.1508	14.0078	14.00	Range Safety	3.857 = 3h 51m
C2W	9.6656	11.3967	11.433	Medical	1.768 = 1h 46m
C2F	9.5894	15.7303	16.0047	Normal	6.415 = 6h 25m
C3M	9.7183	14.9169	14.9333	Medical	5.215 = 5h 13m
C3W	9.0956	13.3503	13.5775	Normal	4.482 = 4h 29m
C3F	9.0814	13.1069	13.15	Medical	4.069 = 4h 4m

[1]See Table 1-4 for dates. C1M = Crew 1, Monday, etc.

[2]All times except the last column are clock times (EDT) expressed in decimal hours.

Personnel in the exercise were assigned participant identification (PID) numbers denoting their crew and position. Table 1-6 lists each PID.

Table 1-6. Participant identification numbers for the M198 howitzer exercise.

Crew 1	*Crew 2*	*Crew 3*	*Position*
10	20	30	Chief of Section
11	21	31	Gunner
12	22	32	Assistant Gunner
13	23	33	No. 1 Cannoneer (loader)
14	24	34	No. 1 Ammo (projectile handler)
15	25	35	No. 2 Ammo (projectile handler)
16	26	36	No. 1 Powder
17	27	37	No. 2 Powder
18	28	38	Radio Telephone Operator (RTO)
19	29	39	Driver[a] (projectile handler)

[a]In the US Marine Corps the driver is not part of the gun section, but is assigned with his vehicle from the motor section. For this exercise, the driver participated in fire missions (as a projectile handler) following procedures of US Army artillery crews. In this manner, the driver was available to assume or share duties of crewmembers who were pulled for heat strain.

SECTION 2
DATA COLLECTION AND DESCRIPTION OF RECORDED EVENTS

This section describes the method of data collection and the nature of the events recorded for the M198 howitzer fire missions. Although, descriptions are cast in standard U.S. Army terminology as far as possible, evolution of equipment and procedures and limits on documentation available to the authors has likely introduced some nonstandard terminology. The authors have strived for consistency across the three volumes of this report and hope that clarity will result.

2.1. METHOD OF DATA COLLECTION.

The activities of the seven to ten member crew of a 155 mm towed howitzer during a fire mission form a complex network of tasks. A few observers with stopwatches can achieve only a cursory time characterization of such an operation. With a fire rate that approaches one round every 20 or 25 seconds, each observer can reliably measure and write down only one or two time intervals per round. Additional measurements could be obtained from repeated replays of a video tape, but the process would be cumbersome. For such complex crew operations, a better method of observation is desirable.

Fast, portable personal computers provide an economical and powerful alternative to the stopwatch. At the push of a key on its keyboard, a properly programmed computer will read its internal clock and store the tim and the identity of the key pushed. The computer reads and stores much faster than human response times. The data recording rate is determined by how quickly the observer can identify and push the proper alphanumeric keys. Even an unpracticed, hunt-and-peck typist can record data much faster in this way than with a stopwatch, pencil and clipboard. Additionally, the recorded data is in an electronic form convenient for numerical analysis.

To record the activities of the M198 howitzer crew during the P^2NBC^2 artillery test at Aberdeen Proving Grounds in August, 1992, we used a data logger program provided through the courtesy of Dr. Greg King of DNA's Armed Forces Radiobiology Research Institute (AFRRI). The program was written by Mr. Tom Lively of AFRRI. The logger program provides for the convenient construction of a template which associates a numerical code with each event to be observed and then associates each code with one of the computer's alphabetic (letter) keys. Each event is either *impulsive* or *continuous*. For an impulsive event the program records the time at which a letter key is pushed along with the key's event code from the template. The duration of the impulsive event is assumed to be too short for the human observer to measure. Alternatively, the impulsive event may be viewed as a time marking the beginning

or end of an operation. For a continuous event, the logger program starts timing an interval when a key is pushed once and stops the interval when the same key is pushed again. The program records the duration and stop time of the interval along with the key's event code from the template. All times are recorded as elapsed times from the start of the data recording session with a precision of 0.01 seconds. Each data file has a header that includes the template with key assignments and the date and time that the recording session was started. Additionally, the program allows alphanumeric comments to be entered in the data file during a recording session.

The following subsections describe the data logger template used for the M198 exercise. Events are listed by the letter key assigned and title of each event as listed in Table 1-2. The paragraphs include descriptions of the events and cues used for timing from the vantage point of the observers.

2.2. EVENTS RECORDED BY ALL DATA LOGGERS.

Two events in each fire mission were recorded by every data logger.

F .... *Fire*

Each data logger used "F" to mark the firing of the howitzer. Although originally planned as part of the Cannoneers' tasks, at the end of the first day it was apparent that the firing of the howitzer was a useful marker to include in every data file. Analysis of the "F" key strikes in each data file provides continuous calibration of the computer clocks among observers.

Early in the exercise, some variance was introduced in the recording of firing times by the multiple cues for firing: the Chief of Section calls "fire", the No. 1 Cannoneer (Loader) pulls the lanyard, and the howitzer goes off. Although we moved toward cuing on the muzzle blast, there is inevitable anticipation based on the other cues. This anticipation sometimes caused multiple "F" key strikes for a single round, especially on Monday of the second week, when an inexperienced Loader had repeated misfires. We frequently hit "F" every time he pulled the lanyard until he got the howitzer to fire. Usually, the last "F" key strike in a series is the correct one.

On other occasions, multiple key strikes for "F" are spaced too closely (about 0.1 seconds) to have been caused by confusion of events. These multiple strikes may have been caused by key bounce or by operator reflex response to the concussion of firing. In these cases the first key strike is likely to be correct.

Y . .. *End of fire mission*

Each days planned scenario consisted of multiple fire missions with 3 to 25 rounds each. There were always 7 missions planned before resupply and 10 missions planned after. Each data

logger used "Y" to mark the completion of a fire mission. The primary function of "Y" is to organize the data files. "End of mission" was not called in a manner consistent enough to warrant timing. Either the time of the last round fired or the end of the last inspection (swabbing) of the bore are better quantitative indicators of the end of mission for the purpose of data analysis.

2.3. EVENTS RECORDED BY LOGGER NO. 1: MAINLY CANNONEER TASKS.

During fire missions, Logger No. 1 recorded the cannoneer tasks and the receipt and calling out of fire mission orders. Many of the cannoneer tasks involve a team effort. A three-man subgroup prepares and loads the projectiles. Two of them carry the projectile on a tray and the third trails with the ramrod. The Number One Cannoneer does not participate in loading the projectile. Another two-man subgroup prepares the propellant. One man stays near the propellant tent while the other brings the propellant bag to the Number One Cannoneer. The Number One Cannoneer inserts the propellant into the chamber after the projectile has been loaded, closes the breech, inserts a primer, latches the firing mechanism, attaches the lanyard, and fires the howitzer by pulling the lanyard on command from the Chief of Section. After firing the howitzer, the No. 1 Cannoneer opens the breech and swabs the bore in preparation for the next round. Aside from the physical exertion required of the projectile handlers (the "ammo humpers"), the No. 1 Cannoneer is usually the most active crewmember.

O .... *Receive/call out fire mission*

We used "O" to time the receipt and calling out of the fire mission. The first indication of a fire mission is a shrill tone from the communications device on the left trail of the gun. Either the Recorder (RTO man) or the Chief of Section calls out "fire mission" and everyone else repeats the phrase. Then the Chief of Section calls out each element of the orders and receives confirmation from the designated crewmember(s). The last command called out was the quadrant elevation, immediately preceded by the deflection. Logger No. 1 started "O" at the verbal command "fire mission" rather than when the tone sounded. Logger No. 1 ended "O" when the quadrant elevation had been repeated back by the Assistant Gunner.

L .... *Load start (set tray)*

The projectile tray has a leading lip that sets into the rim of the open breech of the howitzer. The verbal command "seat" was used to coordinate the two cannoneers setting the tray into the breech. Logger No. 1 used "L" to record this event. There was a visual cue as the cannoneers hefted the tray into position as well as an audible clunk when the lip of the tray hit the breech rim. The line of sight from our observation point to the breech was nearly always obstructed at

this moment by either the No. 1 Cannoneer, the Chief of Section, or the powder man bringing the propellant bag. Thus, the primary cue for the "L" key strike was the clunk of the projectile tray hitting the breech.

For a normal fire mission, the elevation angle is small enough that full elevation does not impair the ability of the projectile handlers to load the projectile. Therefore, the timing of the "L" event is not dependent on the timing of the *elevate tube/level bubbles* event or vice versa. On the first round of a normal fire mission, the "L" event indicates the time taken for the projectile handlers to prepare the projectile in response to fire mission orders and bring it to the breech.

Generally, on second and subsequent rounds of a fire mission, preparation of the next projectile is done by the time the previous round has been fired. In this case, the projectile handlers are waiting with the projectile on the tray while the No. 1 Cannoneer swabs the breech and inspects the tube to insure that the bore is clear of residue from the previous round. Therefore, the preparation of the projectile is not a rate limiting event. However, procedural differences were noted from crew to crew. Typically, the projectile handlers would bring the tray within a few feet of the breech during the swabbing of the breech and be ready to seat the tray immediately after the No. 1 Cannoneer cleared the area. On some days, the projectile handlers were more cautious, waiting as far as 15 or 20 feet from the breech until the swab and bore inspection were complete. This procedure required additional time for movement to the breech.

H .... *Ram projectile*

The sequence of verbal commands used by the projectile handlers was "seat, home, ready, ram." Logger No. 1 used "H" to mark the audible clink at the end of the ram as the projectile is seated (reaches its stopping point) in the chamber. An advance cue is provided by the cannoneers beginning the ramming motion. The vigor of the ram and, therefore, the loudness of seating the projectile varied from round to round. An inaudible seating usually caused the Chief of Section to call for a second ram. In this case, we recorded both rams but use the second as successful completion of loading the projectile.

The opportunity to record the ram event was recognized only after the first week of observations. Therefore, data for the ram event was recorded only for Crews 2 and 3.

J .... *Close breech; prime*

As soon as the projectile handlers clear the breech area, the No. 1 Cannoneer inserts the propellant bag and closes the breech. In preparation, the powder men must have cut the charge to the required level, rewrapped the bag, brought the bag to the howitzer, verified the charge with the Chief of Section, and handed the bag to the No. 1 Cannoneer. This preparation of the charge,

especially at MOPP4, occasionally caused delay. Delay was most likely on the first round of the fire mission since the charge was not known in advance. On subsequent rounds, if all was going well, the No. 1 Cannoneer would finish swabbing the bore from the previous round, turn around, and be handed the next prepared powder bag immediately. Delay became more likely as the crew dropped below the full complement of ten men. When the crew was down to seven, the No. 1 Cannoneer would make the trip to the powder tent himself and sometimes do the cutting or preparation of the charge.

Logger No. 1 started the "J" interval when the breech was slammed shut. The motions of the No. 1 Cannoneer were usually visible, but the main cue was the audible slamming of the breech. Locking the breech was also usually audible but "J" was normally already started. The complex motions and sounds of the breech closing probably increase the variance of recording this event. The No. 1 Cannoneer next reached for a primer, inserted the primer, closed the primer latch, and stepped back. The stepping back movement was usually accompanied by a reach for the lanyard which was either draped around the No. 1 Cannoneer's neck or lying nearby. The stepping back movement varied considerably from man to man. Nevertheless, the clear establishment of movement away from the breech was used as the cue to end "J". Alternatives were no better. Difficulties closing the primer latch necessitated repeated closing attempts, making latch closure an unsuitable marker. Also, the "primed" report from the No. 1 Cannoneer was not consistently audible.

Interpretation of the "J" interval is complicated by differences in the location of unwrapped primers relative to the No. 1 Cannoneer. Usual procedure is to take the primers from a cardboard box located on the right trail five or six feet from the breech. During some tests, however, the US Army Human Engineering Laboratory (HEL) was testing the utility of a primer rack located about two feet from the breech. Another complication is that during one period of reduced crew size, an inexperienced No. 1 Cannoneer did not have the primers prepared in advance and was removing the foil wrapper from each primer during the "J" interval.

In summary, we used the "J" interval to record the time taken to prime the howitzer measured from the closure of the breech to the definite establishment of movement away from the breech by the No. 1 Cannoneer after closing the primer latch. It does not include the time to attach the lanyard to the firing mechanism which occurs at the command *standby*.

I .... *Open breech/swab bore*

Immediately after firing the howitzer, the No. 1 Cannoneer detaches the lanyard, opens the breech, and reaches for the swab in generally continuous motion. Logger No. 1 started the "I" interval at the audible sound of the breech being unlatched. There were no apparent glitches from mechanical problems or human error involved in this step; however, the line of sight was

frequently obstructed by the Chief of Section or a Range Safety Officer. Since the opening of the latch was not loud, additional variance is introduced in the start of this interval. The No. 1 Cannoneer takes the water laden swab, plunges the bore, wipes the breech block, inspects the breech and tube for foreign material, and replaces the swab in the water bucket just inside the left trail of the howitzer. Logger No. 1 stopped the "I" interval as he placed the swab in the bucket.

When the crew was performing near top speed, the projectile tray would be set in the breech ("L") at the same time or even before the swab was placed in the bucket. Some variance on the part of the data logger in both ending "I" and recording "L" is undoubtedly introduced under these circumstances by the unpredictability of which button needs to be pushed first. When "L" is separated by a second or so from the end of "I", this effect should be negligible.

After the last round of a fire mission, the No. 1 Cannoneer takes a little extra time to swab the breech and visually examine the bore of the howitzer.

2.4. EVENTS RECORDED BY LOGGER NO.2: MAINLY GUNNER TASKS.

During fire missions, Logger No. 2 recorded the Gunner tasks and the command "Standby" delivered by the Chief of Section. The Gunner tasks from the observers vantage point provided only visual cues based on somewhat indistinct motions. Familiarity of the observer with the mechanics of the gun sight was essential. We frequently had two observers recording Logger No. 2 data. There is usually general agreement between the two observers but occasionally significant differences. The variance between two observers is indicative of the indistinctness of the visual cues that consist of relatively minor head and hand motions.

U .... *Set deflection*

On receipt of the four-digit deflection for the fire mission, the Gunner turns a crank (azimuth knob) located on his right at eye level on the panoramic telescope to adjust a mechanical register (the azimuth counter) to the deflection setting. Logger No. 2 used "U" to record the time at which the gunner put his hand to the crank. The Gunner had available an electronic display of the deflection setting for the mission allowing him to set the deflection before receiving the oral numbers from the Chief of Section.

Note that the time to set the deflection must be found by calculating the interval from the impulse event "U" to the beginning of the "P" interval as discussed below.

P .... *Traverse tube/level bubble*

Immediately after setting the deflection numbers on the azimuth counter, the Gunner moves his right hand to a crank handle on a large wheel located to his right side at about waist level.

Turning this wheel traverses the gun to the correct azimuth (deflection). To know when he has reached the correct deflection, the Gunner must look into the gun sight (the panoramic telescope, a periscope-like device) to align his crosshairs with a survey marker. Final setting of the traverse is done by adjusting the wheel with the right hand while peering into the gun sight. When the gunner is finished with this task, he moves his hand from the wheel and pulls his head away from the sight. The nature of these moves varies from one Gunner to the next.

Logger No. 2 started "P" when the Gunner began turning the hand wheel to accomplish the traverse. Logger No. 2 ended "P" when the Gunner took his hand off the wheel and stepped back from the gun sight.

Note that the beginning of the "P" interval marks the end of the *set deflection* event since the Gunner traverses the tube immediately after setting the deflection. For analysis, the time to set the deflection will be calculated by finding the difference between the impulse event "U" and the initiation of the continuous event "P".

See "K .... *Check sight picture*" below for a discussion of the definition of end of the traverse. The measurement was treated differently for Crew 1 than for Crews 2 and 3.

R .... *Standby*

Logger No. 2 used "R" to record the verbal command *standby* delivered by the Chief of Section. All fire missions in this exercise were conducted under the special instruction "at my command." Under this procedure, the No. 1 Cannoneer primes the howitzer but does not attach the lanyard until the Chief of Section determines that all is ready. This procedure permits the Range Safety Officer to conduct a safety check prior to clearing the howitzer to be fired. At the command *standby*, the No. 1 Cannoneer attaches the lanyard and at the command *fire* from the Chief of Section, he pulls the lanyard. These two commands are usually delivered about a second apart during which time the Chief of Section glances around to be sure that all personnel are clear of the howitzer recoil.

Two of the Chiefs of Section drew out the *standby* command as two long syllables with emphasis on the second. A systematic variance would occur between observers who key on different syllables. This issue was not recognized or discussed by the observers during the exercise.

K .... *Check sight picture*

After each round is fired, the Gunner must check to see that the howitzer is still on the proper deflection angle, that is, that the gun sight's cross hairs are still aligned. He steps back to the gun sight and makes any necessary adjustments in traverse to realign his sight picture. We started "K" when the Gunner put his head to the sight and ended "K" when he stepped back from

the sight.

Because of inexperience among the team of observers and ambiguity in instructions, Logger No. 2 changed the procedure for recording *traverse tube* and *check sight* midday on Monday of the second week. The ambiguity arose because the Gunner pauses after executing the traverse, to wait for the Assistant Gunner to complete elevation of the tube, before checking the sight and making final adjustment of the deflection angle if necessary. During the first week and on Monday morning of the second week, Logger No. 2 terminated the *traverse tube* event at the start of the pause and switched to the *check sight* event at the end of the pause when the Gunner made the final adjustment of the deflection angle. Starting on Monday afternoon of the second week, Logger No. 2 extended the *traverse tube* event to encompass the pause and the final adjustment of the deflection.

2.5. EVENTS RECORDED BY LOGGER NO. 3: MAINLY ASSISTANT GUNNER TASKS.

During fire missions, Logger No. 3 recorded the Assistant Gunner tasks and the safety checks imposed by range safety procedures. From our vantage point, the Assistant Gunner tasks provided only visual cues based on somewhat indistinct motions. Observations were further inhibited by our position relative to the Assistant Gunner. The Assistant Gunner's right arm was away from us since he was on the right side of the howitzer facing toward the gun tube while we were 30 m or so to the left rear of the breech. Also, the Assistant Gunner checks bubble-type level indicators to set the elevation of the gun rather than looking into an eyepiece. It was not possible to distinguish with any reliability his glances to see if the bubbles still indicated level after each round was fired.

Familiarity of the observer with the mechanics of the howitzer was again essential. We frequently had two observers recording Logger No. 3 data. There is usually general agreement between the two observers but also significant differences. The variance between two observers is indicative of the indefiniteness of the visual cues consisting of relatively minor head and hand motions viewed from a distance.

Q .... *Set quadrant elevation (QE) on range quadrant*

The Assistant Gunner receives a 3 or 4 digit elevation angle (in milliradians or "mils") which he sets into a mechanical register (part of the range quadrant) by turning a small crank at about eye level with his right hand. When the correct value is set, the Assistant Gunner vigorously turns a medium-sized crank wheel to hydraulically bring the gun tube to the proper elevation angle.

Logger No. 3 used "Q" to mark the time at which the Assistant Gunner reached for the small crank to set the elevation angle into the mechanical register. To conserve key strokes for the

observer, the end of the set elevation task is taken as the beginning of the elevate tube ("E") interval since there is no significant delay between the two tasks. Thus, for analysis, the set elevation task time is calculated as the interval between the impulse "Q" event and the beginning of the "E" interval.

The Assistant Gunner receives the quadrant elevation angle in two ways, first as a digital display on a small, gun display unit (GDU) to his left on the right trail of the howitzer and, second, as a verbal command from the Chief of Section. The experienced crewmembers would read the elevation from the display, enter it, and frequently elevate the tube by the time the Chief of Section called the elevation. In this case, the Assistant Gunner would repeat back the verbal command followed by the response "set" to indicate completion of the task. Occasionally, an inexperienced crewmember rotated to the Assistant Gunner position would wait for the verbal command before setting the elevation on the range quadrant and elevating the tube.

Often, the Assistant Gunner was aided in his tasks by the Gunner. Zone and sweep missions require frequent changes in aim point and high angle missions require the tube to be depressed after every round for loading and then to be re-elevated for firing. For these missions, particularly, the Gunner would use a duplicate elevation crank wheel on his side of the howitzer to assist with the work load of the Assistant Gunner. Finally, when the number of crewmembers had been reduced by heat exhaustion, the Gunner would assume all tasks of the Assistant Gunner as well as his own.

Such variations in procedure coupled with frequent passage of other crewmembers through the observer's line-of-sight to the Assistant Gunner will contribute to the variance of measured times for the *set elevation* event.

E .... *Elevate tube/level bubbles*

Logger No. 3 started the interval "E" when the Assistant Gunner (or Gunner) reached for and began turning the crank to elevate the gun tube. This time also marks the end of the *set elevation* ("Q") event since the Assistant Gunner would go directly from setting the elevation to elevating the tube. Logger No. 3 ended the "E" interval when the Assistant Gunner indicated his satisfaction with the elevation of the howitzer tube by taking his hand off the elevation crank wheel and taking one step back from the howitzer. This interval includes the time for the Assistant Gunner to verify that the range quadrant bubbles indicate level.

The original intent was to use the "E" interval to record the time taken for the Assistant Gunner to level the bubbles on the range quadrant after each round was fired. We found, however, that there were not sufficient visual cues to time this task. Furthermore, consultation with an Assistant Gunner verified that, as a rule, no adjustments were required. His glances at

the bubbles to check for a level condition were not apparent to us, so we gave up timing this verification task.

For high angle missions, the elevation angle of the tube must be lowered after firing to allow loading of the next projectile. (See "D" below.) Logger No. 3 used the "E" interval to record the time taken to return the elevation to the proper angle for the next firing. For the zone and sweep missions, the aim point is adjusted in a regular fashion during the firing of the 25 rounds. Logger No. 3 used "E" to time the corresponding changes in elevation for either increases or decreases in elevation angle.

The variations in procedure between the Assistant Gunner and the Gunner and the less than optimal line-of-sight to the Assistant Gunner's position will contribute to the variance of measured "E" intervals as discussed above under the description of the "Q" task.

D .... *Depress tube for loading*

For high angle missions, the howitzer tube must be depressed (have its elevation angle lowered) after each round is fired to allow the Cannoneers to load and ram the projectile for the next round. After a successful ram is achieved, the tube must be returned to the required elevation.

Logger No. 3 started the "D" interval when the Assistant Gunner (or the Gunner) began turning the crank wheel to lower the elevation angle. We ended the "D" interval when turning of the wheel to lower the angle ceased. Note that in contrast to the "E" event which must bring the elevation angle to the ordered value for the fire mission, the "D" event does not require a fine adjustment of angle at the end for loading.

S .... *Safety check*

Range safety procedures required a formal verification of the aiming or laying of the gun by safety personnel and an announcement of impending live fire by two loud whistles before the first round of each mission could be fired. We used the interval "S" to time this procedure for later removal from the overall mission time.

Logger No. 3 started the "S" interval when the No. 1 Cannoneer had primed the howitzer for the first round of each fire mission. The start of "S" should therefore coincide with the end of the "J" (*close breech; prime*) interval as recorded by Logger No. 1. At this point the Gunner has already reported "ready" to indicate that both the deflection and elevation angles are set properly. The Chief of Section, noting that the howitzer is primed and the No. 1 Cannoneer is at attention, reports "gun safe and ready to fire." Safety checks are then made. After the Range Safety Officer is satisfied that the howitzer is aimed within the physical limits of the safety range fan, he blows two whistles and the Chief of Section gives the order *standby* to the gun crew.

We end the "S" interval at the *standby* command. Therefore, the end of "S" should correspond to the *standby* event "R" as recorded by Logger No. 2.

Occasionally, a primer misfire, an aircraft overflight, or a boat intrusion on the firing range would require an intervention and check fire by the Range Safety Officer. We used "S" to time these intervals as well. Logger No. 3 started "S" as soon as we became aware of the problem (a somewhat variable event) and ended "S" with the subsequent *standby* command.

SECTION 3
EVENT DATA

This section discusses data reduction and reconciliation procedures leading to processed data files that contain final measured times for each of the events described in Section 2. This section also describes event timelines constructed for each fire mission from these data files.

3.1. DATA REDUCTION AND RECONCILIATION.

Figure 3-1 provides an overview of the data processing and analysis procedure highlighting the data reconciliation steps. During field collection of the data, events to be recorded were divided among three primary human observers or data loggers (McClellan, 1992). On certain exercise days, fourth and sometimes fifth data loggers provided backup measurements for one or two of the three primary loggers. Events recorded by each of the data loggers are described in Section 2. Data reduction begins with a time correction to the field-collected data from each of the data loggers. The time corrections are made according to computer clock calibrations described in Volume 1 of this report. Briefly, a linear correction formula derived from recorded howitzer firing times is used to synchronize each computer clock to the computer used by Logger No. 1.

The time-corrected data files are used to generate preliminary event listings and to construct preliminary graphical representations of the data in the form of timelines for each fire mission. Where there is a backup data logger, the preliminary listings and timelines include the redundant measurements for comparison.

The preliminary listings and timelines were examined manually to reconcile redundant measurements, eliminate errors when possible, and select a final measured time for each event. The reconciliation process is discussed further in Volume 1. Final, reconciled event data files for each primary logger are the result of this process.

3.2. EVENT TIMELINES FOR FIRE MISSIONS.

As indicated in Figure 3-1, reconciled event data for the three primary loggers is merged into two event data files for each day of the exercise, one file for fire missions before resupply and one for fire missions after resupply. The time origin for the data files is the "move to firing point" order (see McClellan, 1992). Final event timelines for each fire mission are constructed from these merged event files. Figure 3-2 shows an example of such a timeline for Fire Mission 9 of Crew 3 in MOFP4-R, the last fire mission of the exercise. Impulse events are marked by filled triangles and continuous events are marked with horizontal lines. Event times correspond to the lower tips of the triangles and to the vertical hash marks at either end of the lines.

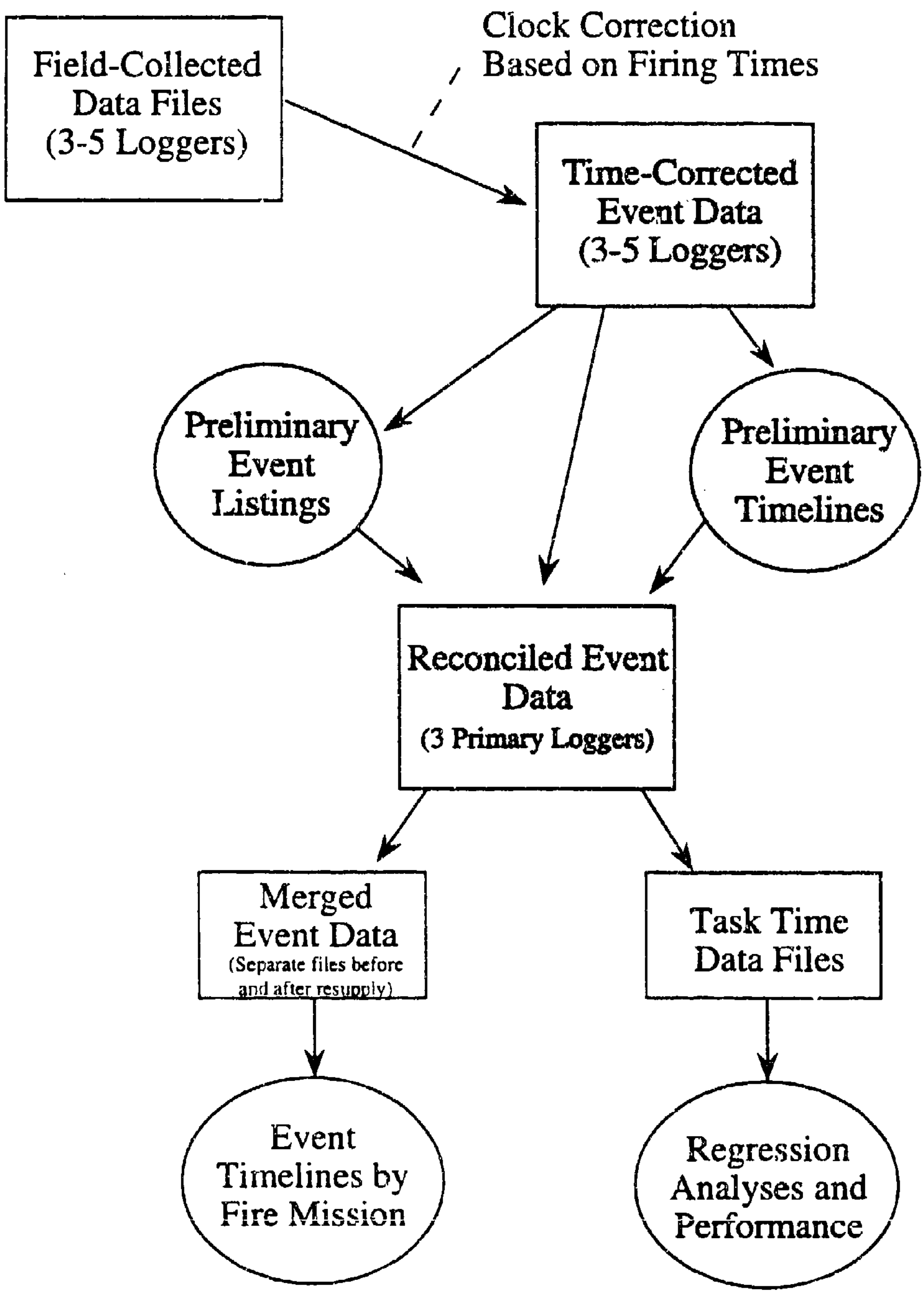


Figure 3-1. Overview of data processing and analysis procedure with data reconciliation steps shaded.

Appendix A presents a timeline for each fire mission analyzed in this report, that is, all fire missions except the high angle and zone and sweep types. The visual presentation provided by the timelines is quite useful for a quick impression of the flow of events and provides a convenient reference for examining anomalies encountered in the analysis of task times derived from the data. Anomalies such as the double ram in Figure 3-2 can frequently be correlated with comments recorded by the data loggers during the exercise. These comments are included fire mission-by-fire mission in Appendix B. In addition, the timeline plots are accurate and provide a quantitative representation of the event data.

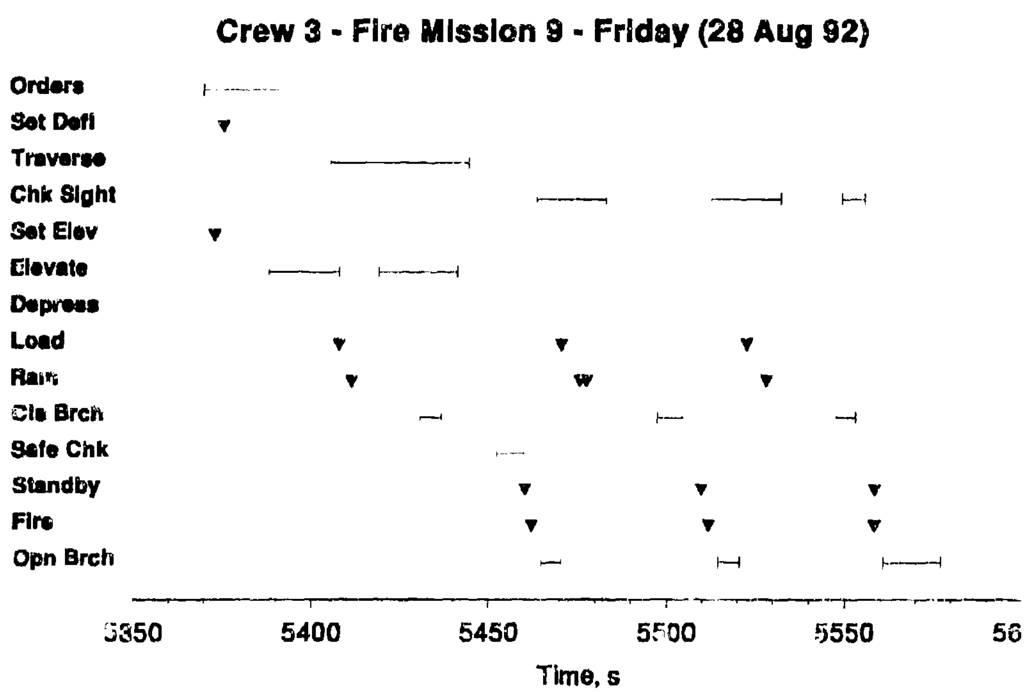


Figure 3-2. The timeline for measured events from Fire Mission 9 of Crew 3 in MOPP4-R. See Appendix A for an explanation of event abbreviations and the origin of the time coordinate.

SECTION 4
DEFINITION AND ANALYSIS OF TASK TIMES

Times recorded in the field correspond to events that are readily discernible by the observers. These event times are used in subsequent analysis to calculate the task times of interest for crewmember performance. This section presents task definitions in terms of the events recorded during the M198 howitzer fire missions. Then, task times are analyzed and compared across crews for each crew posture following the analytical procedures developed in Volume 1. Finally, baseline task times for calculating performance in MOPP4 are derived from the BDU data.

4.1. M198 TASK DEFINITIONS.

The following paragraphs describe each M198 howitzer crew task defined from the recorded events presented in Section 2. The recorded events are of two types, impulsive and continuous. The continuous events correspond to tasks or groups of tasks of direct interest for describing M198 fire missions. On the other hand, the impulsive events of Section 2 provide only the beginning or end of a task. For impulsive events, the task time to be calculated is the interval between the impulsive event and some other recorded time. The other time may be a second impulsive event or the start or end time of a continuous event. Table 4-1 summarizes how each task time is calculated from the recorded event times. Here, and elsewhere in this report, *event names* are in *italics* and **task names** are **bolded**.

Relay Orders

The **relay orders** task time is the duration of the *receive/call out fire mission* continuous event as described in Section 2.3. The beginning of this task is the beginning of the fire mission; a sequential network analysis based on our measurements may be referenced to this time point.

Begin Set Deflection

The **begin set deflection** task time is the time taken for the Gunner to respond to the fire mission orders and begin to set the deflection angle. It is calculated as the time interval from the start of the *receive/call out fire mission* continuous event to the *set deflection on sight* impulsive event. The **begin set deflection** task time can be negative, since the Gunner may obtain the deflection from his gun display unit (GDU) before the Chief of Section begins calling out the orders. The time will be in the 10 or 20 second range if the Gunner waits to receive the deflection angle orally.

Table 4-1. Definition of tasks (in **bold**) for M198 howitzer fire missions in terms[a] of field-recorded events (in *italics*).

Relay Orders	= Duration[*Receive/call out fire mission*]
Begin Set Deflection	= Time[*Set deflection on sight*] - Start[*Receive/call out fire mission*]
Set Deflection	= Start[*Traverse tube/level bubble*] - Time[*Set deflection*]
Traverse Tube	= Duration[*Traverse tube/level bubble*]
Begin Set Elevation	= Time[*Set QE on range quadrant*] - Start[*Receive/call out fire mission*]
Set Elevation	= Start[*Elevate tube/level bubbles*] - Time[*Set QE on range quadrant*]
Elevate Tube	= Duration[*Elevate tube/level bubbles*]
Begin First Load	= Time[*Load start (set tray)*; 1st round[b]] - Start[*Receive/call out fire mission*]
Load Projectile	= Time[*Ram projectile*] - Time[*Load start (set tray)*]
Load First Powder	= Start[*Close breech/prime*; 1st round] - Time[*Ram projectile*; 1st round]
Load First Projectile and Powder[c]	= Start[*Close breech/prime*; 1st round] - Time[*Load start (set tray)*; 1st round]
Lock Breech and Prime	= Duration[*Close breech/prime*]
Fire	= Time[*Fire*] - Time[*Standby*]
Open Breech	= Start[*Open breech/swab bore*] - Time[*Fire*]; except last round of fire mission.
Swab Chamber	= Duration[*Open breech/swab bore*]; except last round of fire mission.
Check Sight	= {Σ Duration[*Check sight picture*; all rounds]}/(# of rounds - 1)
Begin Reload	= Time[*Load start (set tray)*; repeat rounds[d]] - End[*Open breech/swab bore*]
Reload Powder	= Start[*Close breech/prime*; repeat rounds] - Time[*Ram projectile*; repeat rounds]
Reload Projectile and Powder[c]	= Start[*Close breech/prime*; repeat rounds] - Time[*Load start (set tray)*; repeat rounds]
Last Open Breech	= Start[*Open breech/swab bore*] - Time[*Fire*]; last round of fire mission only.
Swab and Inspect	= Duration[*Open breech/swab bore*]; last round of fire mission only.

[a]The square bracket notations in the table have the following meanings:

Time[*event*] = recorded time of an impulse event.
Start[*event*] = starting time of recorded interval for a continuous event.
End[*event*] = ending time of recorded interval for a continuous event.
Duration[*event*] = duration of recorded interval for a continuous event.

[b]1st round = first round of a fire mission.

[c]This task is a combination of the two preceeding tasks. See text for discussion.

[d]repeat rounds = second and succeeding rounds of a fire mission.

Set Deflection

The **set deflection** task time is the time taken by the Gunner to enter the deflection angle on the gun sight as described in Section 2.4. It is the time interval between the *set deflection* impulsive event and the start of the *traverse tube/level bubble* continuous event.

Traverse Tube

The **traverse tube** task time is the duration of the *traverse tube/level bubble* continuous event as described in Section 2.4. For the Crew 1 data, **traverse tube** includes just the time to turn the hand wheel in the accomplishment of the gross motion of the howitzer tube through the required deflection angle. For Crews 2 and 3, **traverse tube** also includes the final check of the deflection angle and any intermediate pause for the completion of the tube elevation.

Begin Set Elevation

The **begin set elevation** task time is the time taken for the Assistant Gunner to respond to the fire mission orders and begin to set the quadrant elevation angle. It is calculated as the time interval from the start of the *receive/call out fire mission* continuous event to the time of the *set QE on range quadrant* impulsive event as described in Section 2.5. The **begin set deflection** task time can be negative, since the Assistant Gunner may read the elevation angle from his GDU before the Chief of Section begins calling out the orders. It will be in the 10 or 20 second range if the Assistant Gunner waits to receive the elevation angle verbally.

Set Elevation

The **set elevation** task time is the time taken by the Assistant Gunner to enter the elevation angle on the range quadrant as described in Section 2.5. It is the time interval between the *set QE on range quadrant* impulsive event and the start of the *elevate tube/level bubbles* continuous event.

Elevate Tube

The **elevate tube** task time is the duration of the *elevate tube/level bubbles* continuous event as described in Section 2.5.

Begin First Load

The **begin first load** task time is the time taken by the projectile handlers to prepare the first projectile in response to the fire mission orders and bring it to the howitzer as described in Section 2.3 It is calculated as the time interval from the start of the *receive/call out fire mission*

continuous event to the time of the *load start (seat tray)* impulsive event for the 1st round of the fire mission.

Load Projectile

The **load projectile** task time is the time taken by the projectile handlers to ram the projectile into the chamber after seating the projectile tray in the breech of the howitzer as described in Section 2.3. It is calculated as the interval from the time of the *load start (seat tray)* impulsive event to the time of the *ram projectile* impulsive event. There is no distinction for this task between the first round of a fire mission and subsequent rounds.

Load First Powder

The **load first powder** task time is the time taken by the No. 1 Cannoneer after the first projectile of the fire mission has been loaded to place the powder (propellant) bag into the chamber and close the breech as described in Section 2.3. The time is calculated as the interval from the time of the *ram projectile* impulsive event to the start of the *close breech/prime* continuous event. This task time encompasses the insertion of the powder into the breech as well as any prior wait time if the powder bag has not reached the No. 1 Cannoneer by the time the projectile has been loaded. This wait time is likely to be more significant on the first round of a fire mission than on subsequent rounds because the size of the charge must be gotten from the mission orders for the first round, whereas the same charge is used on subsequent rounds.

Load First Projectile and Powder

The **load first projectile and powder** task time is the sum of the **load first projectile** and **load first powder** task times. It is calculated as the interval from the time of the *load start (seat tray)* impulsive event for the first round of the fire mission to the start of the *close breech/prime* continuous event for the same round. This combined task is included for two reasons. First, the *ram projectile* impulsive event was not recorded for Crew 1, so there is no way to separate the tasks for the Crew 1 data. Second, the questionnaire assessment of performance degradation given to the crew members during the exercise included only the lumped task time.

Lock Breech and Prime

The **lock breech and prime** task time is the duration of the *close breech/prime* task as described in Section 2.3.

Fire

The **fire** task time is the time taken by the No. 1 Cannoneer to attach the lanyard in response the command "standby" from the Chief of Section and then fire the howitzer in response to the "fire" command from the Chief of Section. It includes time taken by the Chief of Section to verify that all personnel are clear of the recoil. It is calculated as the interval between the time of the *standby* impulsive event and the time of the *fire* impulsive event.

Open Breech

The **open breech** task time is the time taken by the No. 1 Cannoneer after he has fired the howitzer to detach the lanyard from the firing mechanism and unlatch the breech block. It is calculated as the interval from the time of the *fire* impulsive event to the start of the *open breech/swab bore* continuous event. Frequently, this task time is longest after the last round of the fire mission, presumably because the Loader relaxes somewhat after the last round is fired. Therefore, in this analysis, **open breech** refers the task for all rounds except the last of a fire mission.

Swab Chamber

The **swab chamber** task time is the time taken by the No. 1 Cannoneer to retrieve the swab from its water bucket, plunge the bore, wipe the breech block, and return the swab to the water bucket after each round of a fire mission except the last. It is calculated as the duration of the *open breech/swab bore* continuous event as described in Section 2.3. After the final round of a fire mission, the No. 1 Cannoneer performs the same task with a little more care and also visually inspects the bore; this task after the last round is analyzed separately.

Check Sight

The **check sight** task time is the time taken by the Gunner to verify that the howitzer tube is at the correct deflection angle (sight picture) after each round is fired (except the last, of course). For each round it is the duration of the *check sight picture* continuous event as described in Section 2.4. As far as the observers were concerned, this task was the least well defined, offering the poorest cues for reliable measurement. As a result, two observers usually varied substantially in their recording of this task. As a consequence, we are analyzing only the mean task time per round for each fire mission. Even this mean has substantial variance across fire missions and should not be used for any critical purpose. Fortunately, **check sight** was never observed to be a critical event in the sense that any other task was delayed because of it. As analyzed here, it is estimated as the sum of the durations of all *check sight picture* continuous

events during a fire mission divided by the number of rounds in the fire mission less one (the last).

Begin Reload

The **begin reload** task time is the time taken by the projectile handlers to seat the projectile tray in the breech in preparation for loading the next round after a round is fired and the chamber is swabbed as described Section 2.3 It is calculated as the time interval from the end of the *open breech/swab bore* continuous event to the time of the *load start (seat tray)* impulsive event on second and successive rounds of the fire mission. This time is usually much shorter than the **begin first load** task time.

Reload Powder

The **reload powder** task time is the time taken by the No. 1 Cannoneer after a round has been fired and the next projectile of the fire mission has been loaded to place the powder (propellant) bag into the chamber and close the breech as described in Section 2.3. The time is calculated as the interval from the time of the *ram projectile* impulsive event to the start of the *close breech/prime* continuous event. This task time encompasses the insertion of the powder into the chamber as well as any prior wait time if the powder bag has not reached the No. 1 Cannoneer by the time the projectile has been loaded.

Reload Projectile and Powder

The **reload projectile and powder** task time is the sum of the **reload projectile** and **reload powder** task times. It is calculated as the interval from the time of the *load start (seat tray)* impulsive event after a round has been fired to the start of the *close breech/prime* continuous event for the next round. This combined task is included for two reasons. First, the *ram projectile* impulsive event was not recorded for Crew 1, so there is no way to separate the tasks for the Crew 1 data. Second, the questionnaire assessment of performance degradation given to the crew members during the exercise included only the lumped task time.

Last Open Breech

The **last open breech** task time is the time taken by the No. 1 Cannoneer after he has fired the last round of a fire mission to detach the lanyard from the firing mechanism and unlatch the breech block. It is calculated as the interval from the time of the *fire* impulsive event to the start of the *open breech/swab bore* continuous event. Frequently, the task time is longest after the last round of the fire mission, presumably because the Loader is no longer under pressure to make way for the next projectile. Therefore, the task time after the final round is analyzed by itself.

Swab and Inspect

The **swab and inspect** task time is the time taken by the No. 1 Cannoneer after the last round of a fire mission to retrieve the swab from its water bucket, plunge the bore, wipe the breech block, visually inspect the bore, and return the swab to the water bucket. It is calculated as the duration of the *open breech/swab bore* continuous event after the last round as described in Section 2.3. This task time is generally longer than the **swab chamber** task time because of the added visual inspection of the bore and because the pressure of executing the fire mission has ended.

4.2. TASK TIMES.

Task completion times for the above defined tasks are calculated from the reconciled event data described in Section 3. As illustrated in Figure 3-1, task time data files are used for regression analysis of task time variations and for calculation of performance versus time in MOPP4. This subsection describes the analysis of the task times.

4.2.1. Regression Analysis of Task Times.

Task time data is presented fully in Appendix C. For each task and each crew posture, Appendix C provides two figures and two tables summarizing regression analysis of the corresponding task time data. These figures and tables follow analytical procedures and formats similar to those developed in Volume 1 for the analysis of time to first round and time between rounds. Figure C-1 shows measured task completion times for **relay orders** plotted versus *scenario time* (see Appendix A) for each crew in BDU. Figure C-2 shows the aggregated data from Figure C-1 plotted versus fire mission number, the repetition number for this task.

Each plot in Figures C-1 and C-2 includes a regression line with a 68% confidence band. Table C-1 presents a statistical summary for these regression lines. The task time data for **relay orders** and most other tasks have been transformed with the $\log_{10}$ function to improve the normality of the distributions for regression analysis. The rational for this transformation is presented in Volume 1. Figure 4-1 presents added evidence that the logarithmic transformation improves the normality of the task time data.

Figure 4-1 compares chi-squared tests of the normality of the aggregate **reload powder** task completion times for Crews 2 and 3 with crewmembers in BDU. This task is chosen because there is reasonable consistency between the two crews and little change in task time over the scenarios. The chi-squared test shows that there is only a 1.7% chance of obtaining the observed asymmetry of the distribution of the untransformed task time data in such a trial if the untransformed data were normally distributed. On the other hand, there is 9.8% chance of obtaining the observed distribution if the log transformed data were normally distributed. For

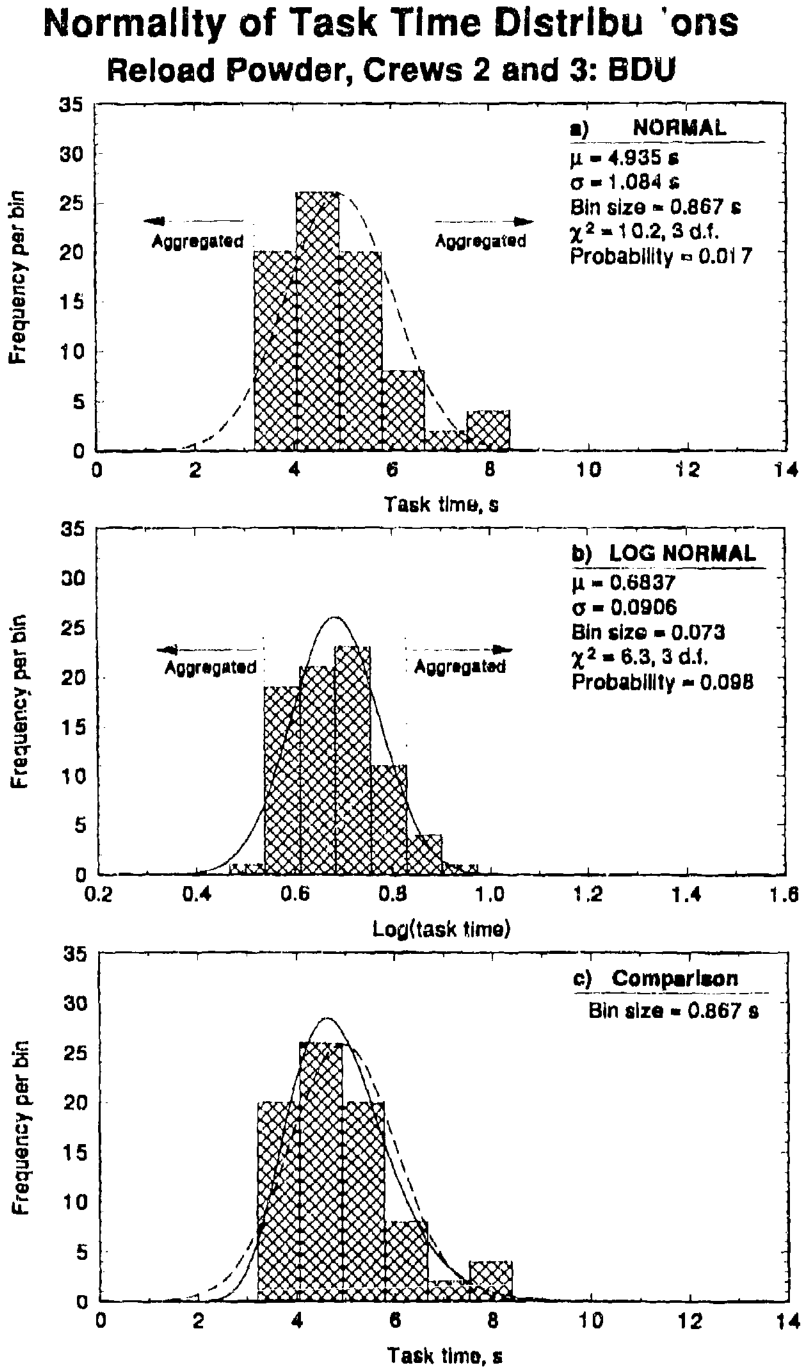


Figure 4-1. Chi-squared test for normality shows that the **reload powder** task time distribution is more nearly log n· mal (b) than normal (a); (c) compares on same time scale.

the chi-squared tests, data outside the indicated limits on the tails of the distribution have been lumped into single bins. The comparison in Figure 4-1c shows that the log normal curve (solid line) better describes the tails of measured distribution.

Plots in Appendix C for the transformed task times are semilogarithmic, as in Figures C-1 and C-2, so that regression results appear as straight lines.Only three tasks have not had their times transformed: **begin set deflection, begin set elevation**, and **begin reload**. These "task times" measure the start of a task relative to another event time. They are actually delays or relative times rather than task completion times. For reasons discussed in the task definitions above, these quantities may be negative, rendering the log transformation impossible. For these three tasks, the data is analyzed without transformation and both axes of the corresponding plots in Appendix C are linear. Although not proper task times, the data are included for completeness since the "tasks" are under the control of crewmembers and are needed for a sequential network analysis of the crew operation.

Table C-1 includes the constant and slope with standard errors for each regression line in Figures C-1 and C-2. Since task times are measured in seconds and the **relay orders** data are transformed before regression analysis, the constant and its standard error are in units of log(seconds). The slope and its standard error are in log(seconds) per hour for Figure C-1 and in log(seconds) per fire mission for Figure C-2. Other quantities in Table C-1 have appropriate corresponding units.

The figures and tables in Appendix C for the tasks with crewmembers in BDU have the same format and units as those for **relay orders** if their task times have been log transformed. For the three tasks for which times are not transformed, the constant and its standard error are in units of seconds; the slope and its standard error are in units of seconds per hour for the individual crew plots and seconds per fire mission for aggregate plots.

The figures and tables for task data with crewmembers in MOPP4 (both -S and -R) differ from the BDU data in one respect. For the MOPP4 data, the independent variable for the regression analysis and the abscissa for all plots is *time in MOPP4*. Thus, slopes are either in log(seconds) per hour or seconds per hour depending on whether the task time data is transformed or not. Scenario time and time in MOPP4 differ by only a few minutes as discussed in Appendix A.

4.2.2. Analysis of Variance and Aggregation of Crew Data.

Table C-2 presents an analysis of variance (ANOVA) for the **relay orders** data from the three crews. The final entry in the table, the "Prob. Value of F", is a statistical measure of the probability that the observed differences of task time distributions from crew to crew would occur randomly if the crews had identical performance characteristics. If "Prob. Value of F" is greater

than or equal to .05, then the observed differences are judged insignificant. It is then statistically valid to aggregate the data from all crews and assert that aggregate results are characteristic of the crews.

If "Prob. Value of F" is less than .05, then the performance of the crews cannot be considered equivalent. Table C-2 shows that "Prob. Value of F" is less than 10^{-5} for **relay orders** in BDU. Indeed, inspection of Figure C-1 shows clear differences among the crews with Crews 1, 2, and 3 having successively lower task times. Appendix C presents aggregate plots and regression analyses even when "Prob. value of F" <.05 since it is sometimes useful to have a single performance representation even if crews are not equivalent.

Aggregate data in Appendix C for crews in BDU is presented and analyzed as task time versus repetition number rather than task time versus scenario time. This choice follows the observation in Volume 1 that overall crew performance in BDU as measured by time to first round and time between rounds shows a tendency to improve somewhat during each day's scenario. This improvement is attributed to a practice or warmup effect and is presumably related to the number of repetitions of the task rather than to time elapsed during the mission scenario. Aggregate plots as well as individual crew plots for data with crewmembers in MOPP4 are presented and analyzed versus time in MOPP4 since performance degradation due to heat stress is expected to be more important than practice or warmup effects.

The straightforward ANOVA test for equivalency of crews does not consider the variation of crew performance over time or repetition number. When there are changes over time, the distributions will be broadened and the ANOVA will tend to underestimate crew differences.

4.2.3 Outliers.

The distribution of times measured for a given task will inevitably contain *outliers*, that is, points that deviate an unreasonable amount from the mean of the distribution. If the task times (or their logarithms) are normally distributed, then the significance of a deviation can be judged quantitatively with a statistical test. Outliers are identified by setting a probability threshold below which values are unlikely to belong to a normal distribution of measured times for the given sample. Alternatively, observations regarding extraneous factors affecting the data may be used to designate outliers.

The analysis in this volume includes a careful treatment of outliers. Measurements for each task have been examined and correlated with field comments (Appendix B) recorded by the data loggers. Appendix D contains a detailed discussion of the rational for the designation of outliers for each task time.

Outliers may result from either observer error or crew error. Whenever possible, observer errors have been eliminated from the data with redundancy and consistency checks. However,

since not all data had redundant measurements, there are likely to be undetected observer errors present in the reconciled data. Further elimination of such errors could be accomplished by analysis of the videotape record of the exercise. This procedure, essentially requiring a complete remeasurement of all event times, would be labor intensive and has not been done. Present analysis is based on the assumption that observer errors do not make a dominant contribution to the variance of task times. Special cases in which likely observer errors can be eliminated by defining outliers are noted in Appendix D.

An outlier from crew error may result from a procedural change or an outright blunder by one or more crewmembers. Outliers of this type are infrequent when the crew is well trained and using well designed equipment. Such outliers are an important part of crew performance analysis if they adversely impact crew survival; however, they are not of primary importance when general performance degradation from a battlefield stressor is the central issue, as it is in the present study of artillery crew performance.

Field notes taken by observers during the exercise are an important source of information to identify outliers caused by crew errors. For example, on a few rounds (out of 581), the ram was not sufficiently vigorous to properly seat the projectile in the chamber of the howitzer. On these occasions, the ram was repeated at the command of the Chief of Section. On one occasion with the crew in MOPP4, no one noticed an ineffective ram and the projectile subsequently fell out of the breech onto the ground as the projectile handlers started to moved away. Such errors are always corrected by the crew and were usually noted in writing by the observers. When the correction process requires substantial time, the resulting task time outlier can be correlated with the written comments by the observers.

Appendix B presents a transcription of notes taken by the observers who logged task time data during the exercise. Although these notes are certainly not exhaustive, they frequently explain obvious outliers.

Finally, consideration must be given to maintaining consistency in the task time being measured. In certain instances, procedural changes caused significant variation in task time. The dominant cause is the loss of crewmembers during the MOPP4 exercises and the subsequent adjustment of task load among crewmembers. Whenever possible, outlier limits are chosen to maintain consistency in the task time being measured for an individual crewmember. In this way, calculated performance degradation is relevant to individual tasks and does not reflect the higher order effects of crew interactions under stress. This latter issue is important but not addressed in this report.

Table 4-2 lists upper and lower limits that are used to define task time outliers for each crew and each posture. Outliers designated by these criteria are plotted with separate symbols (solid circles) in the task time figures for individual crews in Appendix C and are not used in regression

Table 4-2. Upper and lower limits defining outliers for the task time measurements.

Task	*Outlier limits in seconds*					
	BDU		*MOPP4-S*		*MOPP4-R*	
	Lower	*Upper*	*Lower*	*Upper*	*Lower*	*Upper*
Relay orders	17.0	100.0	25.0	100.0	17.0	100.0
Begin set deflection	-100.0	13.0	-100.0	15.0	-100.0	13.0
Set deflection	2.5	17.5	2.5	17.5	2.5	17.5
Traverse tube[a]	10.0	30.0	10.0	38.0	13.0	38.0
Begin set elevation	-5.0	10.0	-5.0	15.0	-5.0	15.0
Set elevation	2.5	17.5	2.5	17.5	3.5	17.5
Elevate tube	-100.0	35.0	13.0	35.0	13.0	35.0
Begin first load	19.0	90.0	19.0	90.0	19.0	90.0
Load projectile	1.0	9.0	1.0	9.0	2.4	9.0
Load first powder	-100.0	20.0	5.0	35.0	-100.0	35.0
Load first projo and pwdr	-100.0	20.0	-100.0	30.0	-100.0	30.0
Lock breech and prime	2.0	10.0	2.0	10.0	2.0	15.0
Fire	1.0	5.3	1.0	8.0	1.0	8.0
Open breech	1.0	3.5	1.0	5.0	1.0	5.0
Swab chamber	3.5	9.0	4.0	15.0	4.0	15.0
Check sight	2.0	100.0	3.0	100.0	2.0	100.0
Begin reload	-2.0	20.0	-2.0	20.0	-2.0	20.0
Reload powder	-100.0	10.0	-100.0	10.0	-100.0	10.0
Reload projo and pwdr	-100.0	15.0	-100.0	15.0	-100.0	15.0
Last open breech	1.0	4.5	1.0	5.0	1.0	5.0
Swab and inspect	7.0	100.0	7.0	100.0	5.0	100.0

[a]Applies only to Crews 2 and 3 (**Traverse tube II**).

analyses or in the analysis of variance. Furthermore, the outlier data points are not carried forward to crew aggregate plots nor to subsequent performance calculations.

4.2.4. Summary of Task Time Regressions and ANOVA.

Appendix C presents figures and tables for each task following the order of the task definitions in Section 4.1. The order generally follows the cycle of tasks to prepare and fire the first round and then to prepare and fire subsequent rounds. For convenience of visual comparison, data for all three crew postures (BDU, MOPP4-S, and MOPP4-R) are grouped together for each task. The following discussion summarizes results for each posture separately.

Table 4-3 summarizes the signs of the slopes of the regression lines from Appendix C for each task and each crew in BDU. The table also includes from Appendix C the "Prob. Value of F" from the ANOVA and, if the value is greater than or equal to 0.05, the sign of the slope of the aggregate regression line. Table 4-3 shows that most task times showed no statistically significant change over the 17 fire missions of each scenario. When there is a significant slope, a majority of the cases (6 of 9) show a task time decreasing with scenario time (a negative slope), but there is no apparent pattern across tasks or crews. For no task did more than one crew show a significant slope.

The practice or warmup effect reported in Volume 1 for the overall rates of fire in BDU is not a prominent feature of the BDU task data summarized in Table 4-3.

Table 4-4 summarizes the similar information for MOPP4-S, that is, for scenarios with crewmembers in MOPP4 with standard crew positions. In this case, when there is a significant slope for individual crew data, the majority of the cases (11 of 15) show a task time increasing with time in MOPP4 (a positive slope). The ANOVA results show that performance was equivalent among crews for 10 out of 21 tasks with only one of these, **load first projectile and powder**, having a significant (positive) slope.

Table 4-5 summarizes the same results for MOPP4-R, that is, for scenarios with crew in MOPP4 using a regimented rotation of crew positions to distribute the thermal work load. Only Crews 2 and 3 performed this scenario. As with MOPP4-S, when there is a significant slope for individual crew data, the majority of cases (7 of 8) show a task time increasing with time in MOPP4 (a positive slope). The ANOVA results show that task time distributions for the two crews were equivalent for 16 of 21 tasks. Of the 16 equivalent cases, 5 had significant positive slopes (worsening performance with time in MOPP4) and none had significant negative slopes.

Table 4-3. Summary of regression slopes and ANOVA results for crews in BDU.

Task	*Sign of slope*[a] *Crew* 1	2	3	*ANOVA Prob. value of F*	*Sign of slope*[b] *Aggregate data*
Relay orders	o	-	o	0.000	
Begin set deflection	o	+	o	0.006	
Set deflection	o	o	o	0.873	o
Traverse tube I	o				
Traverse tube II		o	o	0.676	o
Begin set elevation	o	o	o	0.014	
Set elevation	o	o	+	0.492	o
Elevate tube	o	o	o	0.191	o
Begin first load	-	o	o	0.000	
Load projectile		o	o	0.000	
Load first powder		o	o	0.176	o
Load first projo and pwdr	o	o	o	0.005	
Lock breech and prime	o	-	o	0.000	
Fire	-	o	o	0.000	
Open breech	o	o	-	0.000	
Swab chamber	o	o	o	0.005	
Check sight	o	o	-	0.010	
Begin reload	o	o	o	0.000	
Reload powder		o	o	0.095	o
Reload projo and pwdr	o	o	o	0.008	
Last open breech	o	o	o	0.002	
Swab and inspect	o	+	o	0.000	

[a]Sign of slope is "o" if *prob t* from regression analysis is >0.05, that is, no statistically significant slope. Blank entry means no data available.

[b]Sign of slope from aggregate crew data is quoted only if the ANOVA gives a *Prob. value of F* >0.05, that is, there are no statistically significant differences in task time distribution among the crews. The ANOVA results show that performance was equivalent among the crews for only 6 out of 21 tasks. For these 6 tasks, none of the regression analyses of the aggregate task time data showed a statistically significant variation of task time with repetition number.

Table 4-4. Summary of regression slopes and ANOVA results for crews in MOPP4-S.

Task	*Sign of slope*[a] *Crew* 1	2	3	*ANOVA Prob. value of F*	*Sign of slope*[b] *Aggregate data*
Relay orders	o	o	o	0.087	o
Begin set deflection	o	o	+	0.954	o
Set deflection	-	o	o	0.008	
Traverse tube I	o				
Traverse tube II		o	o	0.024	
Begin set elevation	o	+	+	0.100	o
Set elevation	o	-	o	0.839	o
Elevate tube	o	o	o	0.729	o
Begin first load	-	o	o	0.035	
Load projectile		-	+	0.046	
Load first powder		o	o	0.043	
Load first projo and pwdr	o	o	+	0.464	+
Lock breech and prime	o	+	o	0.000	
Fire	o	+	o	0.000	
Open breech	o	o	o	0.470	o
Swab chamber	o	o	+	0.002	
Check sight	o	o	o	0.320	o
Begin reload	o	o	+	0.264	o
Reload powder		o	o	0.000	
Reload projo and pwdr	+	o	+	0.000	
Last open breech	o	o	o	0.720	o
Swab and inspect	o	o	o	0.002	

[a]Sign of slope is "o" if *prob t* from regression analysis is >0.05, that is, no statistically significant slope. Blank entry means no data available.

[b]Sign of slope from aggregate crew data is quoted only if the ANOVA gives a *Prob. value of F* >0.05, that is, there are no statistically significant differences in task time distribution among the crews.

Table 4-5. Summary of regression slopes and ANOVA results for crews in MOPP4-R.

Task	*Sign of slope*[a] *Crew*			*ANOVA Prob. value of F*	*Sign of slope*[b] *Aggregate data*
	1[c]	*2*	*3*		
Relay orders		o	o	0.757	o
Begin set deflection		o	o	0.054	o
Set deflection		o	o	0.107	o
Traverse tube I					
Traverse tube II		o	-	0.435	o
Begin set elevation		+	o	0.381	o
Set elevation		o	+	0.589	o
Elevate tube		o	o	0.056	+
Begin first load		o	o	0.587	o
Load projectile		o	+	0.725	o
Load first powder		o	o	0.086	+
Load first projo and pwdr		o	o	0.198	+
Lock breech and prime		o	o	0.002	
Fire		o	o	0.437	o
Open breech		o	o	0.011	
Swab chamber		+	o	0.001	
Check sight		o	o	0.000	
Begin reload		o	o	0.017	
Reload powder		+	+	0.132	+
Reload projo and pwdr		+	o	0.146	+
Last open breech		o	o	0.271	o
Swab and inspect		o	o	0.569	o

[a]Sign of slope is "o" if *prob t* from regression analysis is >0.05, that is, no statistically significant slope. Blank entry means no data available.

[b]Sign of slope from aggregate crew data is quoted only if the ANOVA gives a *Prob. value of F* >0.05, that is, there are no statistically significant differences in task time distribution among the crews.

[c]Crew 1 did not conduct a scenario in MOPP4-R.

Taken together, the MOPP4-S and MOPP4-R regression analyses for individual crews have 5 cases of significant negative slope (improving performance) and 18 cases of significant positive slope (worsening performance) consistent with the expectation that heat stress associated with the MOPP gear is a dominant effect on the time dependence of performance. Of the 5 cases of negative slope, 3 are Gunner or Assistant Gunner tasks and 2 are Cannoneer tasks. Of the 18 cases of positive slope, 5 are Gunner or Assistant Gunner tasks and 13 are Cannoneer tasks. These observations indicate that the Cannoneer tasks are more susceptible to heat stress-induced performance degradation than Gunner and Assistant Gunner tasks. Additionally, the Gunner and Assistant Gunner tasks may be more susceptible to learning or practice effects that compensate for the encumbrance of the MOPP gear.

4.3. BASELINE TASK TIMES.

A performance measure based on task completion time is used to express the performance degrading effects of MOPP gear in this analysis. Specifically, performance P in MOPP gear is expressed as the ratio of a normative or baseline task completion time t_0 to the task completion time t in MOPP gear:

$$P = t_0 / t . \tag{4-1}$$

The mean task completion time in BDU is used as the baseline time for each task. Since a main focus of the present analysis is the determination of performance as a function of time in MOPP4, an important step is the selection of an appropriate baseline for measurements at different times in MOPP4.

4.3.1. Factors Influencing Selection of Baseline Times.

Table 4-3 shows that there are two important considerations in the selection of baseline times. First, the ANOVA results show that for most tasks, the three crews do not perform equivalently in BDU. In these cases, it is necessary to use separate baselines for each crew. When the ANOVA shows consistency among the crews as indicated in Table 4-3, a common baseline determined from the aggregate crew data is used.

Second, Table 4-3 shows that for each crew there are a few tasks with statistically significant variation of mean task time over the scenario. Most of the slopes are negative, that is, the baseline time tends to decrease over time. This decrease is attributed to a warmup effect as discussed in Volume 1. It occurs in BDU in spite of the variation of order of the BDU scenario within the daily exercise schedule for the different crews. In fact, the data for Crew 1 in BDU is from its third day of scenarios, the second day in BDU. Since there is no correlation with

scenario order, it is assumed that the negative slopes represent a variation that would occur on any day of operations, rather than a learning effect that would go away with practice. If the slope is due to warmup each day, then the change should be related to the number of repetitions of the given task. Therefore, regression analysis of task time versus repetition number is used to predict baseline times, whether for individual or aggregate crew data.

4.3.2. Regression Prediction of Baseline Times.

Table 4-6 summarizes the regression coefficients for the calculation of baseline task times in BDU versus repetition number for each task and each crew. If the coefficients are identical for all crews, they are from the regression analyses of aggregate crew data appearing in Appendix C. If the coefficients are different for each crew, they are from regression analyses of the individual crew data sets. These individual regressions versus repetition number use the data as shown in Appendix C, but are not shown explicitly in this report. The regression lines summarized in Table 4-6 are used to calculate baseline task times for each repetition even when Table 4-3 shows that the data is statistically consistent with no slope. This choice yields valid estimates for all baseline times and avoids treating slopes of the tasks differently based on the arbitrary choice of the 5% level of statistical significance used in Table 4-3.

The data in Table 4-6 is included in digital form in the file README.TXT on the diskette that accompanies this report.

4.3.3. Uncertainty in Baseline Times.

It is useful to characterize the root mean square (rms) deviation as well as the mean of the task times in BDU. A graphical characterization is provided in Appendix C by the 68% confidence band plotted with each regression line. This band is narrowest along the regression line at a value of the repetition number (independent variable) corresponding to the mean of the task time (dependent variable) for the data points in each set. The *standard deviation of the estimate* listed in the tables in Appendix C for each regression analysis characterizes the half width of the narrowest point of the 68% confidence band. For large samples, the width of the 68% confidence band at this point is equal to twice the standard deviation of the estimate. For smaller samples as in Appendix C, the 68% band calculated from Student's t-distribution is wider than two standard deviations.

Table 4-6. Regression results used to calculate baseline task times and uncertainty limits as a function of repetition number.

Task	Data[a] Trans.	Rep.[b] no.	Crew 1		Crew 2		Crew 3		Aggregate	
			const.	slope	const.	slope	const.	slope	s.d.	s.e.
Relay orders	log	FM	1.5577	-0.00825	1.4445	-0.00895	1.3470	-0.00088	0.079	0.028
Begin set deflection	none	FM	4.7207	0.14559	2.7714	0.26961	12.5908	-0.24950	2.843	1.146
Set deflection	log	FM	0.7077	0.00273	0.7077	0.00273	0.7077	0.00273	0.146	0.052
Traverse tube I	log	FM	0.6225	0.00700					0.137	0.080
Traverse tube II	log	FM			1.2739	-0.00148	1.2739	-0.00148	0.111	0.054
Begin set elevation	none	FM	3.8650	0.32500	2.2947	-0.09530	10.5905	-0.40368	3.249	1.548
Set elevation	log	FM	0.7711	0.00631	0.7711	0.00631	0.7711	0.00631	0.130	0.049
Elevate tube	log	FM	1.3443	-0.00541	1.3443	-0.00541	1.3443	-0.00541	0.116	0.043
Begin first load	log	FM	*1.4495*	*0.00000*	1.4410	-0.00546	1.3809	0.00182	0.078	0.027
Load projectile	log	Rd			0.5610	-0.00076	0.3426	-0.00020	0.126	0.023
Load first powder	log	FM			0.8980	0.00047	0.8980	0.00047	0.172	0.074
Load first projo and pwdr	log	FM	0.9534	-0.00458	0.9508	0.00971	1.1408	-0.01072	0.123	0.042
Lock breech and prime	log	Rd	0.5292	-0.00035	*0.6262*	*0.00000*	0.5460	0.00013	0.141	0.021
Fire	log	Rd	0.4860	-0.00141	0.3195	0.00007	0.2690	-0.00060	0.160	0.026
Open breech	log	Rd	0.2905	0.00008	*0.4044*	*0.00000*	0.3230	-0.00073	0.092	0.016
Swab chamber	log	Rd	0.6531	0.00038	0.7208	-0.00011	0.7292	-0.00036	0.069	0.012
Check sight	log	FM	0.7731	0.00405	0.3537	0.01895	1.0077	-0.02609	0.186	0.071
Begin reload	none	Rd	1.3786	0.01141	0.2385	-0.00115	0.5155	-0.00211	1.483	0.260
Reload powder	log	Rd			0.6987	-0.00031	0.6987	-0.00031	0.091	0.019
Reload projo and pwdr	log	Rd	0.8653	-0.00002	0.9130	-0.00018	0.8963	-0.00077	0.072	0.012
Last open breech	log	FM	0.2936	0.01121	*0.4606*	*0.00000*	0.3858	-0.00603	0.127	0.046
Swab and inspect	log	FM	0.9665	0.00880	*1.1013*	*0.00000*	0.9740	0.01094	0.120	0.045

[a]If no data transformation has been used, then the constants, the standard deviations (s.d.), and the standard errors (s.e.) are expressed in seconds; otherwise, the quantities are expressed in log(seconds). Likewise, slopes are either in seconds per repetition or log(seconds) per repetition. Logarithms are to the base 10.

[b]The task time [or log(task time)] varies linearly with the repetition number according to the listed constant and slope terms. The repetition number is either fire mission (FM) or round (Rd) number as indicated.

When the data points are sparse and poorly correlated, as with some of the MOPP4 data, the 68% confidence band flares away from the regression line quite markedly relative to the narrowest point because of uncertainty in the slope of the regression line. Fortunately, the flaring is minimal for the BDU data. The standard deviation of the estimate can be used to characterize the spread of task times predicted by the regression line since the BDU data has a well-determined slope resulting in little variation of the width of the 68% confidence band for different repetition numbers (see, for example, Figure C-1). The column labelled *s.d.* in Table 4-6 lists the standard deviation of the estimate from the regression analyses of the aggregate crew data for each task. It characterizes the spread of task times to be expected from repeated measurements of the task time by different crews.

The uncertainty in the determination of the mean of any task time due to the limited number of field measurements is the standard error of the mean. The standard error of the mean predicted by the regression line varies with repetition number in a manner similar to the width of the 68% confidence band. The standard error of the constant as listed in the statistical summary tables of Appendix C is the standard error of the regression line prediction at repetition number 0. In reality there is no repetition number 0 since repetition number starts at 1 by definition. However, the standard error of the constant is convenient as a representative characterization of the uncertainty in the baseline values since the BDU data has a well-determined slope and little variation of either the standard error of the mean or the width of the 68% confidence band for different repetition numbers (see, for example, Figure C-1). The column labelled *s.e.* in Table 4-6 lists the standard error of the constant from the regression analyses of the aggregate crew data for each task.

4.3.4. Special Cases.

As stated before, Table 4-6 shows the constant and slope used to predict baseline task completion times for each crew as a function of task repetition number. Special cases shown in *italics* in Table 4-6 are discussed in the following paragraphs.

Table 4-3 shows that, generally, the individual regression lines for each crew did not have significant slopes. The cases that do have a significant slope have been examined for anomalies. The data for the **begin first load** shows an anomaly for Crew 1 in that, unlike Crews 2 and 3, Crew 1 performed the task slower in BDU than in MOPP4. The Crew 1 time in BDU is much slower than for Crews 2 and 3 for early fire missions, but approaches that of the other crews for the late fire missions. For this reason, the baseline time for Crew 1 for all fire missions in MOPP4 is set equal to the regression line value for Fire Mission 17 in BDU.

Another noticeable anomaly is the **lock breech and prime** task for Crew 2. As noted in Section 2.2 for the *fire* event and in Appendix C for the **fire** task, the Loader for Crew 2, as a

result of inexperience, had trouble with misfires on the first exercise day in BDU, but not on subsequent days in MOPP4. His times for **lock breech and prime** show a very strong learning effect in BDU but not in MOPP4. Therefore, the baseline time for Crew 2 for all fire missions in MOPP4 is set equal to the regression line value for Fire Mission 17 in BDU. This value is about 4.5 s in contrast to about 3.5 s for the other crews.

There are other anomalies associated with the Crew 2 Loader. The anomaly for the **fire** task is fixed by the liberal application of a long-time outlier criterion. The situations for the **open breech** and **last open breech** tasks are similar to that for **lock breech and prime** so, once again, the baseline time for all MOPP4 fire missions is set equal to the regression line value for Fire Mission 17 in BDU for these two tasks. The **swab chamber** task times for the Crew 2 Loader are reasonably consistent with those of the Crew 1 and Crew 3 Loaders and do not show a learning effect, so the baseline times from the regression line are accepted without change. Apparently, the **swab chamber** task was more familiar or easier than the others for the Crew 2 Loader. The **swab and inspect** task after the last round might be expected to be closely equivalent to the **swab chamber** task. Interestingly, the performance of the Crew 2 Loader deteriorated significantly in BDU with a positive regression slope as shown in Table 4-3. Since this task is performed after the last round of the fire mission and not under time pressure, it is likely that the deteriorating performance is due mostly to the accumulation of stress from the repeated misfires and associated attention (ribbing) from other crewmembers. Accordingly, the baseline time for the **swab and inspect** task for all fire missions for Crew 2 in MOPP4 is set equal to the BDU regression line prediction for Fire Mission 1 in BDU.

In summary, Appendix C presents the full range of task time measurements for M198 howitzer crewmember tasks during fire missions. Carefully selected regression analyses of the data with crewmembers in BDU provide baseline times for calculation of performance on the same tasks in MOPP4.

The task completion times plotted in Appendix C are also included in digital form on the 3.5" diskette that accompanies this report.

SECTION 5
HEAT STRESS AND STRAIN

Heat stress on an individual is the combination of environmental conditions and behavioral factors with which the body's thermoregulatory mechanisms must cope. Heat strain, which may be measured by a variety of physical and psychological indicators, is the body's response to heat stress.

Sources of thermal energy contributing to heat stress are hot objects in the work environment, heated air, ambient thermal radiation including solar, and the metabolic work rate of the individual. Other contributors to heat stress are factors that influence heat transport. These factors increase heat stress by interfering with the body's ability to dispose of excess heat. Such factors include clothing type, ambient air temperature, ambient humidity, wind speed, and the health and physical condition of the individual, especially hydration.

As part of the safety conditions of this exercise, medical personnel monitored the core temperature, heart rate, and skin temperature of each crewmember to limit the amount of heat strain suffered by each. When a crewmember exceeded predetermined physiological limits, he was removed from the exercise. Performance measurements from the exercise, therefore, represent the capability of remaining crewmembers with heat strain less than the exercise limits. The measured performance values are conditional; that is, they represent the capabilities of a crewmember given that he has not reached the specified level of heat strain.

For modeling crew performance, it is useful to separate the calculation of individual performance into two steps. First, estimate the probability that a crewmember is still functioning, that is, has not exceeded a specified level of heat strain. Second, given that the crewmember is still functioning, estimate performance degradation for the given task.

This section presents the available heat stress and heat strain data for the M198 howitzer exercise. This data is analyzed to determine an analytical expression for the probability that heat strain limits have not been exceeded. Finally, a comparison is made with predictions of the P^2NBC^2 Heat Strain Decision Aid (HSDA) program, Version 2.0, which is based on algorithms from the U.S. Army Research Institute for Environmental Medicine (USARIEM).

5.1. METEROLOGICAL DATA.

Table 5-1 summarizes meteorological data for each of the exercise days. Two sets of temperature, humidity, and wind speed data are shown, representing the 15 minute report nearest the exercise start time and that nearest the exercise finish or halt time. The last two columns show the period of time for the day's exercise in decimal hours (EDT) and the average solar insolation during this period. The solar insolation is expressed as the number of watts of sunlight

falling on a square meter of level ground. The average was calculated by integrating a cubic spline curve fitted to hourly average insolation values reported from a nearby meteorological station. Appendix A of Volume 1 includes plots of hourly insolation.

Table 5-1. Meteorological summary for the exercise days (Zubal, 1992).

	Starting Conditions			*Ending Conditions*			*Average Solar Insolation*	
Crew	*Temp* °*F*	*Hum* %	*Wind Ave/Pk kt*	*Temp* °*F*	*Hum* %	*Wind Ave/Pk kt*	*Time Interval EDT*	*Insolation W/m2*
C1M	82	71	5/10	88	58	6/11	10.63 - 16.26	747
C1W	77	81	--	79	68	--	10.29 - 13.20	691
C1F	68	90	3/7	74	79	2/6	9.67 - 13.78	440
C2M	70	92	3/7	72	92	3/5	10.15 - 14.00	148
C2W	76	81	3/6	81	63	2/8	9.67 - 11.43	653
C2F	70	71	3/7	77	54	4/6	9.59 - 16.00	815
C3M	75	84	3/5	81	63	5/8	9.72 - 14.93	784
C3W	79	86	3/4	89	63	4/7	9.10 - 13.58	635
C3F	77	90	5/9	85	71	11/19	9.08 - 13.15	631

Since the crews did not use a camouflage net for this exercise, shading of the crewmembers was negligible with the possible exception of the Assistant Gunner who worked on the north side of the howitzer (aimed westward). Monday for Crew 2 (C2M) was a rainy day. Friday for Crew 2, when they completed their MOPP4-R scenario, was the sunniest day but had the lowest combination of temperature and humidity. Generally, the air temperature was in the range of 75 to 85 °F with relative humidity mostly from 65 to 85%. Note that two corrections have been made in Table 5-1 relative to the same data presented in Table 2-4 of Volume 1, which contained transcription errors for the ending humidity for C1W and the ending average wind speed for C3M. The corrected data are underlined in Table 5-1.

5.2. PHYSIOLOGICAL DATA.

Appendix E presents plots of core temperature, heart rate, and skin temperature (Redmond, 1992) for each crewmember on each day of the exercise for both BDU and MOPP4 conditions.

Core body temperature was measured and transmitted by a capsule swallowed by each crewmember each exercise day. Although this method is somewhat more elegant than the rectal probes formerly used for this kind of exercise, the swallowed capsule has one serious drawback for monitoring heat strain. That is, while the capsule is still in the stomach, a drink of water

drastically affects its temperature reading. The drink causes the temperature of the stomach contents to drop abruptly because of the lower tempe re of the ingested liquid and then to return slowly to core body temperature. At a time that cannot be directly determined from the data, the capsule moves into the small intestine, e tually giving a stable reading of core temperature.

The transmitted signals in Appendix E clearly show the effect of water ingestion. Much of the core temperature data for this exercise is so frequently influenced by drinking water that it cannot be used as a quantitative measure of heat strain. Some of the data could be recovered with a thermal model of the stomach; however, such an effort is beyond the scope of this study.

Skin temperature was measured by sensors at three different locations on the torso. One of the sensor locations had frequent data interruptions and is not used here. The skin temperature plots in Appendix E show the average of the other two sensors. This average offers some promise as an indicator of heat stress but would require careful signal processing to provide a reliable measure. Heart rate data are also plotted in Appendix E. These data are quite noisy, with frequent data dropouts, and would also require careful signal processing to provide reliable data.

In conclusion, further analysis and data processing would be required to use the physiological data presented in Appendix E to generate a quantitative measure of heat strain. The analysis in this report uses the less satisfactory but more reliable choice of quantifying heat stress through *time-in-MOPP4* with auxiliary data specifying crew activity level and environmental conditions.

5.3. CREWMEMBER REMOVAL FROM EXERCISE.

The first safety limitation imposed by medical personnel was that a crewmember's core temperature should not rise above 39.4 °C. Second, a crewmember's heart rate should not exceed 160 beats per minute for more than five minutes at rest nor should it exceed 180 for more than five minutes at work. If any one of these physiological limits were exceeded by a crewmember, he was withdrawn from operations and given medical attention. In addition, crewmembers close to the limits were sometimes examined face-to-face by medical personnel and removed at their discretion. Remaining crewmembers resumed operations with position and task adjustments as necessary. When only six crewmembers remained, the exercise was halted for the day.

All of those crewmembers removed from the exercise by medical personnel were still performing their tasks just before removal, although their conditions varied. Some clearly wanted to continue with the exercise. Others were obviously weakened and did not protest removal. In spite of the heat stress, there were no instances of self-removal.

Table 5-2 summarizes, for each day of the exercise and each individual removed, the removal time, Participant Identification (PID) number, number of fire missions completed, and a qualitative description of the reason for removal. Of course, no crewmember required removal

from the scenarios in BDU. This data allows the construction of Table 5-3, which shows the average number of crewmembers present during 0.2 hour intervals for each scenario in MOPP4. Since each day's scenario was halted when the crew was down to 6 crewmembers, there is no data available for more than 40% attrition.

Table 5-2. Removal of crewmembers by medical personnel because of heat strain limits.

Crew/Day (Posture)	*Removal Time (h)*	*Fire missions completed*	*PID*	*Reason for removal*[a]
C1W (S)	1:42	4	15	Body core temperature, heart rate
	2:12	7	14	Participant felt wobbly, was red-faced
	2:28	7	17	Weak, chills, numb limbs
	2:48	7	--	3 Crewmen "on the brink of temperature and heart rate limits." Medical monitoring recommendation to terminate scenario.
C2W (S)	0:30	0	21	Heart rate
	1:09	3	29	Body core temperature
	1:09	3	27	Shortness of breath
	1:28	6	28	Nausea
C2F (R)	4:26	8	27	Shortness of breath
	5:11	11	25	Pulled by mistake <<<<<NOTE>>>>>
	5:24	11	23	Body core temperature
C3M (S)	2:18	6	36	Body core temperature
	2:55	7	30	Body core temperature
	4:26	7	34	Stomach cramps
	5:02	9	33	Body core temperature
C3F (R)	2:26	7	34	Heat symptoms
	3:15	7	36	Body core temperature
	3:37	7	37	Body core temperature
	4:04	9	32	Body core temperature

[a]The reason for removal as listed in this table was recorded by the DNA observers from word-of-mouth information during the exercise and is an incomplete indication of crewmember condition.

Table 5-3. Number of crewmembers still operating versus time in MOPP4.

Time in MOPP4		Mean crew size during interval (out of 10 unless otherwise indicated)				
		MOPP4-S			MOPP4-R	
Interval (h)	Mean (h)	Crew 1	Crew 2	Crew 3	Crew 2	Crew 3
.0 - .2	.1	10	10	10	10	10
.2 - .4	.3	10	10	10	10	10
.4 - .6	.5	10	9.5	10	10	10
.6 - .8	.7	10	9	10	10	10
.8 - 1.0	.9	10	9	10	10	10
1.0 - 1.2	1.1	10	8.5	10	10	10
1.2 - 1.4	1.3	10	7	10	10	10
1.4 - 1.6	1.5	10	6.35	10	10	10
1.6 - 1.8	1.7	9.5	-	10	10	10
1.8 - 2.0	1.9	9	-	10	10	10
2.0 - 2.2	2.1	9	-	10	10	10
2.2 - 2.4	2.3	8	-	9.5	10	10
2.4 - 2.6	2.5	7.5	-	9	10	9.2
2.6 - 2.8	2.7	7	-	9	10	9
2.8 - 3.0	2.9	6	-	8.6	10	9
3.0 - 3.2	3.1	-		8	10	9
3.2 - 3.4	3.3	-	-	8	10	8.2
3.4 - 3.6	3.5	-	-	8	10	8
3.6 - 3.8	3.7	-	-	8	10	7.1
3.8 - 4.0	3.9	-	-	8	10	7
4.0 - 4.2	4.1	-	-	8	10	6.4
4.2 - 4.4	4.3	-	-	8	10	-
4.4 - 4.6	4.5	-	-	7.2	9.2	-
4.6 - 4.8	4.7	-	-	7	9	-
4.8 - 5.0	4.9	-	-	7	9	-
5.0 - 5.2	5.1	-	-	6.2	9	-
5.2 - 5.4	5.3	-	-	-	8 of 9*	-
5.4 - 5.6	5.5	-	-	-	7 of 9	-
5.6 - 5.8	5.7	-	-	-	7 of 9	-
5.8 - 6.0	5.9	-	-	-	7 of 9	-
6.0 - 6.2	6.1	-	-	-	7 of 9	-
6.2 - 6.4	6.3	-	-	-	7 of 9	-

*As indicated in Table 5-2, one crewmember was pulled by mistake, effectively reducing the sample size at this time.

5.4. FRACTION OF CREWMEMBERS REMAINING VERSUS TIME IN MOPP4.

Figures 5-1 and 5-2 plot the fraction of crewmembers remaining for each MOPP4 scenario as a function of time in MOPP4 for standard and rotating crew positions, respectively. The data values for the plotted symbols are derived directly from Table 5-3. In addition, Figures 5-1 and 5-2 contain a fitted curve for each crew. These curves are calculated with a two-parameter function commonly called a Weibull function:

$$F(t) = \exp[-\ln(2)\times(t/t_{50})^{\gamma}], \tag{5-1}$$

where t_{50} is a parameter with dimensions of time determining when the function drops to 50% of its initial value and γ is a dimensionless parameter determining the slope of the function in the vicinity of t_{50}.

Table 5-4 lists parameter values obtained from the least squares fit for each crew as well as the average value of each parameter for MOPP4-S and MOPP4-R. The solid curves in Figures 5-1 and 5-2 are calculated from Equation 5-1 with the mean parameter values. Because there is no data beyond 40% attrition, the use of these curves at more than 50% attrition is not recommended.

Figures 5-1 and 5-2 show that crewmembers generally persisted longer with the regimented rotation of positions (MOPP4-R) than they did with standard crew positions (MOPP4-S), consistent with the expectation of distributing the thermal work load of crewmembers through the rotation. This observation is illustrated by the mean values of t_{50} in Table 5-4, 5.9 h for MOPP4-R versus 3.7 h for MOPP4-S.

The substantial variation in attrition rate from crew to crew in Figures 5-1 and 5-2 indicates some uncertainty in this analysis. Furthermore, although Crew 2 shows the expected difference between MOPP4-R and MOPP4-S, Crew 3 actually attrited a little sooner for rotating positions than for standard. These variations indicate a need to examine the impact of weather conditions on the exercise.

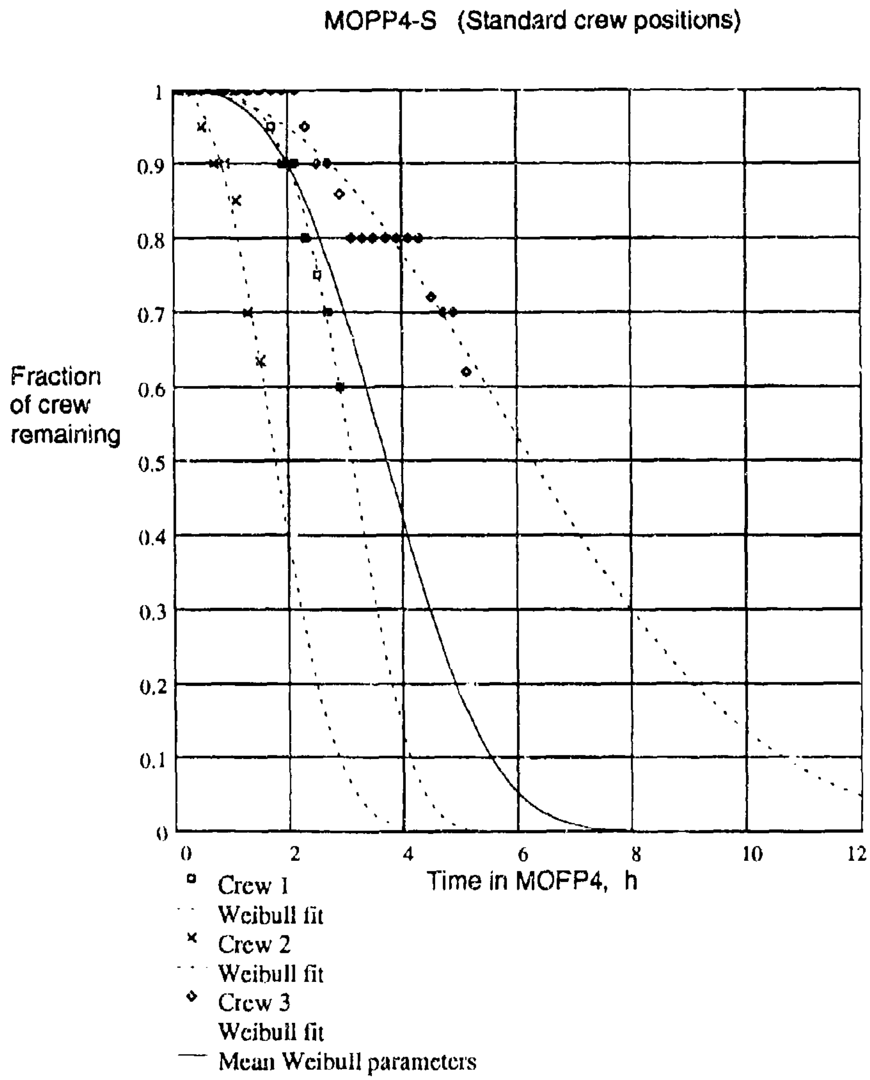


Figure 5-1. Attrition of crewmembers during the MOPP4-S scenarios.

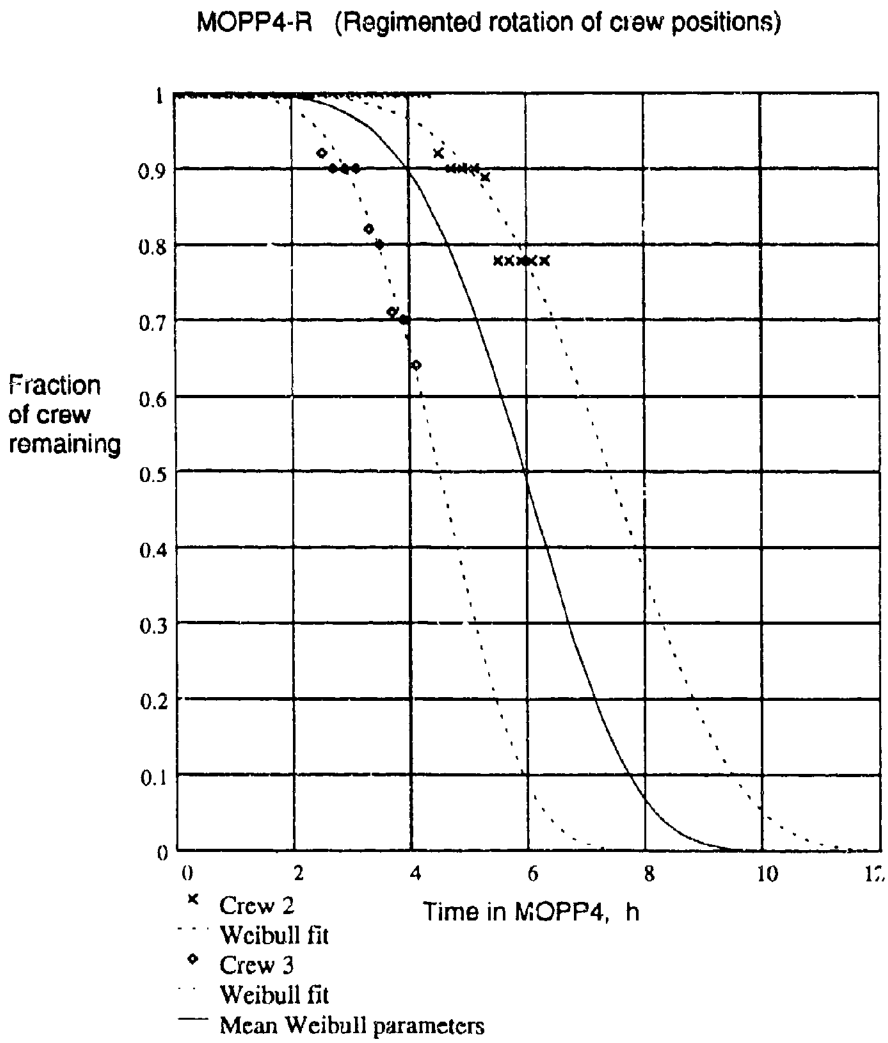


Figure 5-2. Attrition of crewmembers during the MOPP4-R scenarios.

Table 5-4. Parameters for Weibull functions (Equation 5-1) describing the fraction of crewmembers remaining as a function of time in MOPP4 for this exercise[a].

	MOPP4-S		*MOPP4-R*	
Crew	t_{50}, *h*	γ	t_{50}, *h*	γ
1	3.11	4.30	-	-
2	1.77	2.51	7.40	4.84
3	6.27	2.28	4.50	4.35
Mean	3.72	3.02	5.95	4.60

[a]Because of limitations of the data on which these parameters are based, the authors do not recommend extrapolation of these functions beyond 50% attrition.

5.5. IMPACT OF METEOROLOGICAL CONDITIONS.

The impact of meteorological conditions, particularly, ambient temperature, humidity, and wind speed, can be assessed with a thermal model of the human body if it the model includes interaction with the environment. The P^2NBC^2 HSDA code, based on models developed by USARIEM, provides such a capability (McNally et al.,1992). Given the ambient weather conditions and the clothing and activity level of an individual, the code provides, among other things, the time dependent core temperature of the individual.

Figure 5-3 plots core temperature as predicted by the HSDA code for two different activity levels (metabolic work rates) given that the individual is in MOPP4 (Battle Dress Overgarment, closed) and that the ambient conditions are those recorded at the end of the Crew 3 MOPP4-R scenario (C3F) of the M198 exercise. The model indicates that the body core temperature approaches an equilibrium value and is within 0.1 °C of that equilibrium within 2 hours. The characteristic (ie) time for core temperature equilibriation is about 40 minutes. The two curves in Figure 5-3 illustrate the sensitivity of the final core temperature to metabolic work rate. At 310 Watts, the equilibrium temperature is below the safety limit of 39.4 °C for this exercise. At a work rate only 10% higher the limit is exceeded in less than 2 hours.

Table 5-5 shows results from HSDA calculations for each of the exercise days in MOPP4 using metabolic work rate of 310 Watts. The HSDA code is based on steady meteorological conditions. As seen from Table 5-1, actual conditions varied significantly over the several hour extent of each scenario in this exercise. Since the 2 hour equilibration time of core temperature indicated by the HSDA code is less than the scenario lengths, there is time for changes in ambient conditions to affect the outcome of the exercise. The calculations summarized in Table 5-5 use the ambient weather conditions at the end of each scenario as representative of the conditions causing termination of the scenario due to heat strain.

The *final core temperature* listed in Table 5-5 represents the limiting value of core temperature

with a steady metabolic work rate as illustrated in Figure 5-3. Only for the Crew 2 MOPP4-S (C2W-S) conditions does the predicted final core temperature exceed 39.4 °C at a work rate of 310 W. For this case, the core temperature reaches 39.4 °C at 1.7 hours. This time is listed as the *maximum work time* for *no rest* in Table 5-5. The HSDA code also calculates a recommended work/rest cycle for the input weather conditions and activity level. The time to reach 39.4 °C under this work/rest cycle is shown in Table 5-5 as the *with rest* maximum work time. For the Crew 2, MOPP4-S weather conditions, the work/rest cycle increases the maximum work time from 1.7 to 2.8 hours. For the other 4 scenarios in the table, the predicted core temperature equilibrates below 39.4 °C, so the maximum work times are listed as ≥5 hours, the length of the HSDA calculation.

The table also lists the *probability of casualty* estimate of the HSDA code given the work/rest cycle. Finally, Table 5-5 lists the actual mission time recorded for each of the MOPP4 scenarios of the M198 exercise.

Table 5-5. Predictions of the P^2NBC^2 Heat Strain Decision Aid (HSDA) with metabolic work rate of 310 Watts for the MOPP4 scenarios.

	Weather report at end of scenario			*HSDA code predictions*				*Field data*
Crew Day	*Temp*	*Hum*	*Wind*	*Final core temp.*	*Prob. of casual.*	*Maximum work time, h*		*Mission time*
						No rest	*With rest*	
	°F	*%*	*knots*	*°C*	*%*			*h*
C2F-R	77	54	4	39.09	21.4	≥5	≥5	≥6.4
C3F-R	85	71	11	39.23	30.2	≥5	≥5	4.1
C3M-S	81	63	5	39.23	30.3	≥5	≥5	5.2
C1W-S	79	68	3[a]	39.34	38.2	≥5	≥5	2.9
C2W-S	81	63	2	39.51	50.4	1.7	2.8	1.8

[a]Value estimated from written comments of observers which indicated light winds.

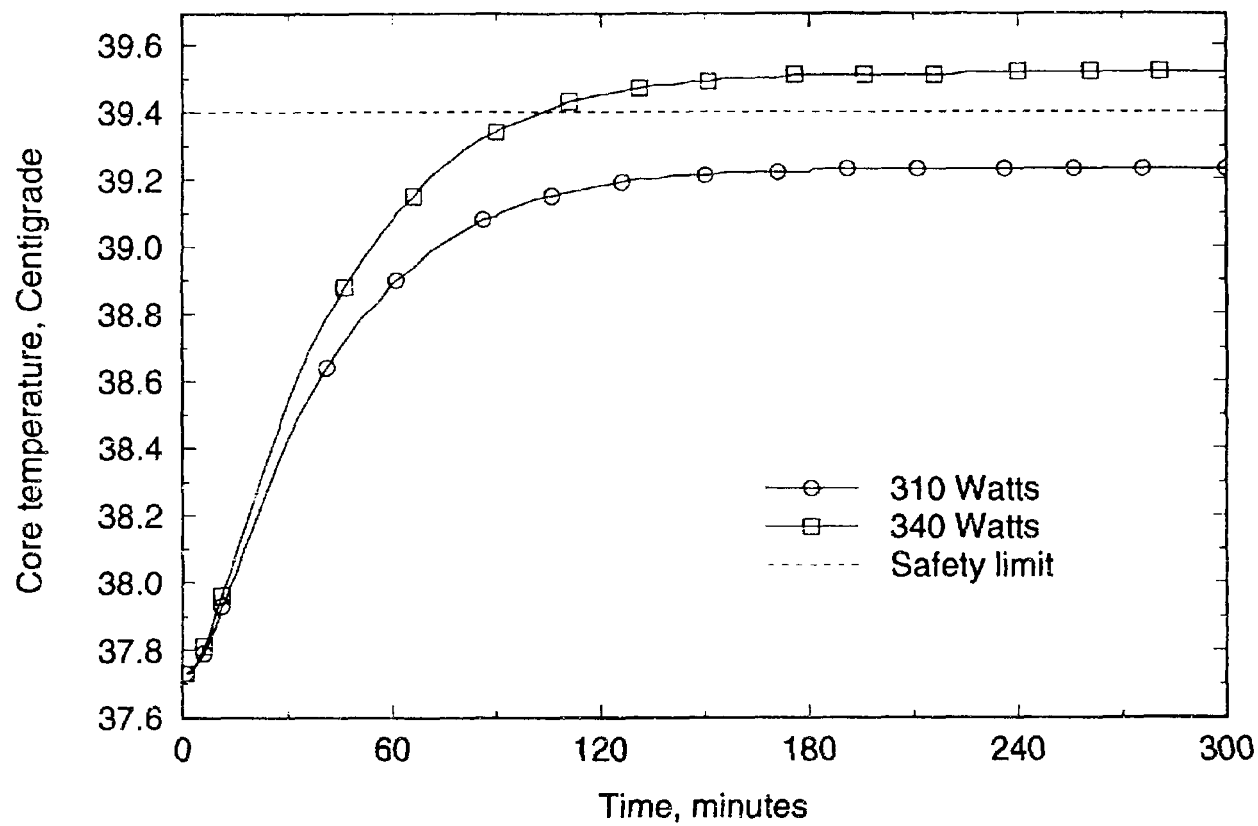


Figure 5-3. Core temperature rise predicted by the Heat Strain Decision Aid code for two metabolic work rates with ambient conditions like those at the end of the MOPP4-S scenario for Crew 3.

The MOPP4 scenarios in Table 5-5 are listed according to increasing values of predicted final core temperature for the recorded weather conditions. It is significant that there is a nearly inverse relationship between the HSDA code prediction for the final core temperature (and the probability of casualty) and the actual mission times accomplished in each of the scenarios. This inverse relationship indicates that meteorology had a significant impact on the outcome of the scenarios.

Table 5-6 presents similar code predictions for an assumed metabolic work rate of 340 W. Here the predicted maximum work times with rest are in closer agreement with the field data and there is an exact agreement between the ordering according to increasing predicted core temperature and that for decreasing mission time from the field data.

Table 5-7 shows typical metabolic work rates for activities comparable to those performed by the M198 howitzer crewmembers. The work rates range from 116 Watts for sitting or standing to 540 Watts for emplacement digging. Activity during the M198 scenarios varied widely. Between fire missions, the crewmembers were usually standing or sitting around with little motion for several minutes. During fire missions, one pair of crewmembers jointly carried projectiles (weighing about 40 kg each) one at a time to the howitzer. Therefore, the rates of 310 and 340 Watts used in the calculations for Tables 5-5 and 5-6 are in a reasonable range for an average.

Table 5-6. Predictions of P^2NBC^2 Heat Strain Decision Aid (HSDA) with metabolic work rate of 340 Watts for the MOPP4 scenarios.

	Weather report at end of scenario			*HSDA code predictions*				*Field data*
Crew day	*Temp*	*Hum*	*Wind*	*Final core temp.*	*Prob. of casual.*	*Maximum work time, h*		*Mission time*
						No rest	*With rest*	
	°F	*%*	*knots*	*°C*	*%*			*h*
C2F-R	77	54	4	39.35	38.7	≥5	≥5	≥6.4
C3M-S	81	63	5	39.52	51.3	1.7	2.7	5.2
C3F-R	85	71	11	39.53	51.9	1.7	2.6	4.1
C1W-S	79	68	3[a]	39.64	60.3	1.4	2.2	2.9
C2W-S	81	63	2	39.81	72.4	1.1	1.8	1.8

[a]Value estimated from written comments of observers indicating light winds.

Table 5-7. Typical metabolic work rates (as quoted within the HSDA code).

Activity	*Metabolic work rate* *Watts*
Standing in foxhole or sitting in truck	116
Guard duty	137
Walking, hard surface, 1 m/s, 20 kg load	255
Walking, loose sand, 1 m/s, no load	326
Walking, hard surface, 1.56 m/s, no load	361
Calisthenics	378
Walking, hard surface, 1.56 m/s, 20 kg load	448
Pick and shovel	465
Emplacement digging	540

5.6. SUMMARY

The following statements summarize findings regarding meteorology and the HSDA code calculations:

1. The HSDA code shows that the characteristic time for core temperature equilibriation is about 40 minutes, significantly shorter than the daily exercise time. Therefore, variations in meteorology during each day's exercise can affect the outcome.

2. The HSDA code predicts about 0.5 °C core temperature variation due to day-to-day variations in meteorology.

3. Variations in meteorology during each day's exercise are comparable to the day to day variation.

4. Equilibrium core temperature is quite sensitive to metabolic work rate; in the regime of this exercise, core temperature increase about 0.3 °C for a 10% (30 Watt) increase in average work rate.

These observations support the following conclusions:

1. It is not a good approximation for modeling or analysis to assume that the environmental conditions were constant for this exercise, either day-to-day or hour-to-hour.

2. Crewmember attrition versus time in MOPP4 are likely to have been strongly influenced by the daily cycle of temperature, humidity, wind, and solar variations and by the time phasing of the scenario relative to the daily cycle.

3. Day to day variations in meteorology can explain a significant part of the variation in mission lengths for the different scenarios.

4. Analysis of the attrition data and the task time data would be improved by modeling the time dependence of both the ambient meteorological conditions and the metabolic work rate.

Finally, additional data analysis would be required to make quantitative use of the physiological data collected during the exercise.

SECTION 6
RESULTS FOR TASK PERFORMANCE IN MOPP4

This section discusses the definition of performance and presents results for task performance versus time in MOPP4. For ease of reference, figures and tables are grouped at the end of this section.

6.1. PERFORMANCE REFERENCED TO BASELINE TASK TIME.

This report measures performance by the time taken for task completion. Although accuracy must be quantified for certain tasks, the M198 tasks listed in Section 4.1 (with three exceptions noted in Section 4.2.1) are all well characterized by their time to completion. These tasks have definite endpoints that must be achieved within tolerance before the fire mission can proceed. Inaccuracies or errors are recognized and corrected by crewmembers at the expense of additional time. Therefore, performance level on a task is well represented by the time taken to do the task right.

With this assumption, *performance p* is defined as the task time ratio

$$p = t_0 / t. \qquad (6\text{-}1)$$

where the normative time t_0 is the time for a well trained crewmember to perform the task when healthy and feeling fine and t is the time taken when the crewmember is stressed or ill. The normative times used in this report are the baseline times with crewmembers in BDU. These baseline times, derived from the regression analysis of multiple trials, are presented and discussed in Section 4.3. With this definition, performance is 1.0 when the task completion time is equal to the baseline time. When task completion time lengthens due to a stressor on the crewmember, performance is less than 1.0. In the extreme case that the crewmember cannot complete the task at all, t is infinite and performance is 0.

Since a task completion time t cannot be negative, the calculated performance value is always positive or zero. Performance values are generally less than or equal to 1; however, two effects can cause performance to be greater than 1, especially for single measured values. First, repeated measurements of the completion time for a given task have a distribution about a mean, so half of the sample of measurements determining the baseline time will be always be faster than the mean. Performance values calculated for this half of the trials are greater than 1 and those calculated for the other half are less than 1. Under mildly stressing conditions with mean performance only slightly less than 1, some trials may still be faster than the mean of the baseline trials, thereby giving performance values greater than 1.0. For this reason, it is

important to keep in mind the standard deviation of the baseline performance distribution when interpreting performance measurements in MOPP4.

Second, procedural changes (shortcuts) by crewmembers in MOPP4 may result in task completion times shorter than normal. It has been reported (Taylor and Orlansky, 1991) that when training in MOPP gear, individuals and crews sometimes learn to modify procedures to reduce the encumbrance effects of the protective clothing. When heat stress is minor, these task modifications may appear as improved performance relative to baseline.

Analysts use a variety of other definitions to quantify performance changes under stressed conditions. One example is the *performance decrement factor* (*pdf*), defined as the multiplier that produces degraded task time from baseline task time:

$$t = pdf \times t_0. \tag{6-2}$$

The *pdf* is the inverse of task performance as defined in Equation 6-1:

$$pdf = t / t_0 = 1 / p. \tag{6-3}$$

Another term is *performance degradation dgr*, usually taken as the complement of performance, that is,

$$dgr = 1 - p. \tag{6-4}$$

Both performance and performance degradation are frequently expressed as percentages. To confuse the matter somewhat, the *percent increase* (*pi*) *in task time*,

$$pi = 100 \times (pdf - 1) \tag{6-5}$$

is occasionally referred to as *percent degradation*. To complicate the issue even further, Taylor and Orlansky (1993) use the term *percent time degradation* D_T defined by

$$D_T = 100 \times (t_0 - t) / t_0 = 100 \times (1 - pdf), \tag{6-6}$$

which is the negative of *pi*. <u>The user of performance data must be alert for changes in definition from one database to the next</u>.

All performance values appearing in this report are task time ratios as defined by Equation 6-1. Note that the logarithmic transformation applied to performance gives

$$\log(p) = \log(t_0) - \log(t). \tag{6-7}$$

Since the logarithm of the task time is normally distributed (see Section 4.2.1), so is the logarithm of performance.

6.2. TASK PERFORMANCE VS. TIME IN MOPP4.

Each task time measured with crew in MOPP4 provides a calculated performance value. This performance is presumably a function of several explanatory variables such as time in MOPP4, task repetition number, scenario, crew identity, crew size at the time of measurement, and meteorology. Only time in MOPP4 is considered explicitly in the following analysis; however, task repetition number is used to select a baseline time for each task measurement in MOPP4.

Let $t(T,N)$ denote the completion time measured in a given scenario for the Nth repetition of a task occurring after T hours in MOPP4. The performance calculated from this measurement is

$$p(T) = t_0(N) / t(T,N), \tag{6-8}$$

where $t_0(N)$ is the baseline completion time for the Nth repetition of the task in BDU (see Table 4-6).

The model used in the regression analyses of performance versus time in MOPP4 is

$$y = a + b \times T + \varepsilon, \tag{6-9}$$

where the parameters a and b are the constant and slope, respectively, and ε is a random error term assumed to be normally distributed with mean value 0. The independent variable is T and the dependent variable y is $\log(p)$.

For the three special cases of **begin set deflection**, **begin set elevation**, and **begin reload** discussed in Section 4.2.1, the data consist of delay times between two events rather than task completion times. For these cases, performance is expressed as the relative delay d, that is, the additional delay in MOPP4 relative to BDU. In these cases, Equation (6-8) is replaced by

$$d(T) = t(T,N) - t_0(N) \tag{6-10}$$

and the dependent variable for the regression analyses is d in seconds.

For simplicity, the performance data from all crews is aggregated for the regression analyses presented below. However, ANOVA results are tabulated to show whether this aggregation is statistically justified and, for visual reference, the data plots use different symbols for each crew.

As discussed in Section 5, when a crewmember exceeded predetermined physiological limits on heat strain, he was removed from the exercise for safety. Performance measurements from the exercise represent the capability of crewmembers with heat strain less than the exercise limits. Therefore, the performance results presented here are conditional; that is, they represent the capabilities of a crewmember given that he has not reached the specified level of heat strain.

The following two subsections present the performance data and regression results for MOPP4-S and MOPP4-R. Each subsection presents a figure for each task with the regression line and a plotted symbol for each performance measurement. In addition, each subsection has a statistical summary in tabular form.

6.2.1. MOPP4 with Standard Crew Positions.

Figure 6-1 plots performance data and regression analysis for the **relay orders** task with crewmembers in MOPP4 using standard crew positions (MOPP4-S). Performance measurements for each crew are distinguished by different plotting symbols as explained in the legend of the figure. The regression line for the aggregate crew data is shown in two ways: 1) as the solid curve plotted in the figure and 2) as the predictor equation included at the upper edge of the plot.

The regression line is flanked by two pairs of curves. The outer pair (dotted) shows the 68% confidence band from the regression analysis. In additional trials, it is expected that 68% of single performance measurements would fall inside this band. The inner pair (dashed) shows ±1 standard error of the predicted mean performance as a function of time in MOPP4 determined from the present data set.

The uncertainty in the baseline values have been neglected in the regression analyses of performance since the standard error of the mean for the baseline predictions is substantially smaller than the spread in the measured task completion times in MOPP4. For reference, the standard deviation of the BDU measurements and the standard error of the mean are plotted as bands about the baseline performance (1.0) in Figure 6-1. These bands may be used to help judge the statistical significance of measured performance degradation in MOPP4. The larger band (the standard deviation) shows the normal variation in baseline performance and provides context for interpreting the occasional performance value in MOPP4 that exceeds 1.

The ordinate in Figure 6-1 is a linear scale of performance. Since the linear regression analysis involves log(p), the regression line in the figure is curvilinear with an asymmetric 68% confidence band. With a logarithmic ordinate, the regression line would be straight and have a symmetric confidence band.

Figures 6-2 through 6-22 present similar information for the remainder of the M198 howitzer crew tasks in the order defined in Section 4 (see Table 4-4). Figure 6-2 presents the data and analysis for **begin set deflection**. Note that the ordinate is linear and is the relative delay in seconds as discussed regarding Equation 6-10. In this case the regression line is straight and the confidence band symmetric. Degraded performance for relative delay is associated with a shift upwards of the curve relative to the baseline delay, that is, degradation corresponds to an increase in relative delay. The same is true for Figures 6-6 and 6-18 covering **begin set elevation** and **begin reload**, respectively.

Table 6-1 provides a statistical summary for the regression lines for each task in MOPP4-S. The last row for each task shows the *Prob. Value of F* for the ANOVA among the three crews. If this value is less than 0.05, there are statistically significant differences in performance among the three crews.

6.2.2. MOPP4 with Regimented Rotation of Crew Positions.

Figure 6-23 plots performance data and regression analysis for the **relay orders** task with crewmembers in MOPP4 using a regimented rotation of crew positions (MOPP4-R). The format and content of the figure parallels that for Figure 6-1 as explained in Section 6.2.1. Figures 6-24 through 6-43 present similar information for the remainder of the M198 howitzer crew tasks in the order defined in Section 4 (see Table 4-5). The ordinates in each figure are performance except for Figures 6-24, 6-27, and 6-39 which plot relative delay as discussed in Section 6.2.1. Table 6-2 provides a statistical summary for the regression lines for each task in MOPP4-R. The last row for each task shows the *Prob. Value of F* for the ANOVA between Crews 2 and 3 (Crew 1 did not conduct a scenario in MOPP4-R). If this value is less than 0.05, there is a statistically significant difference in performance between the crews.

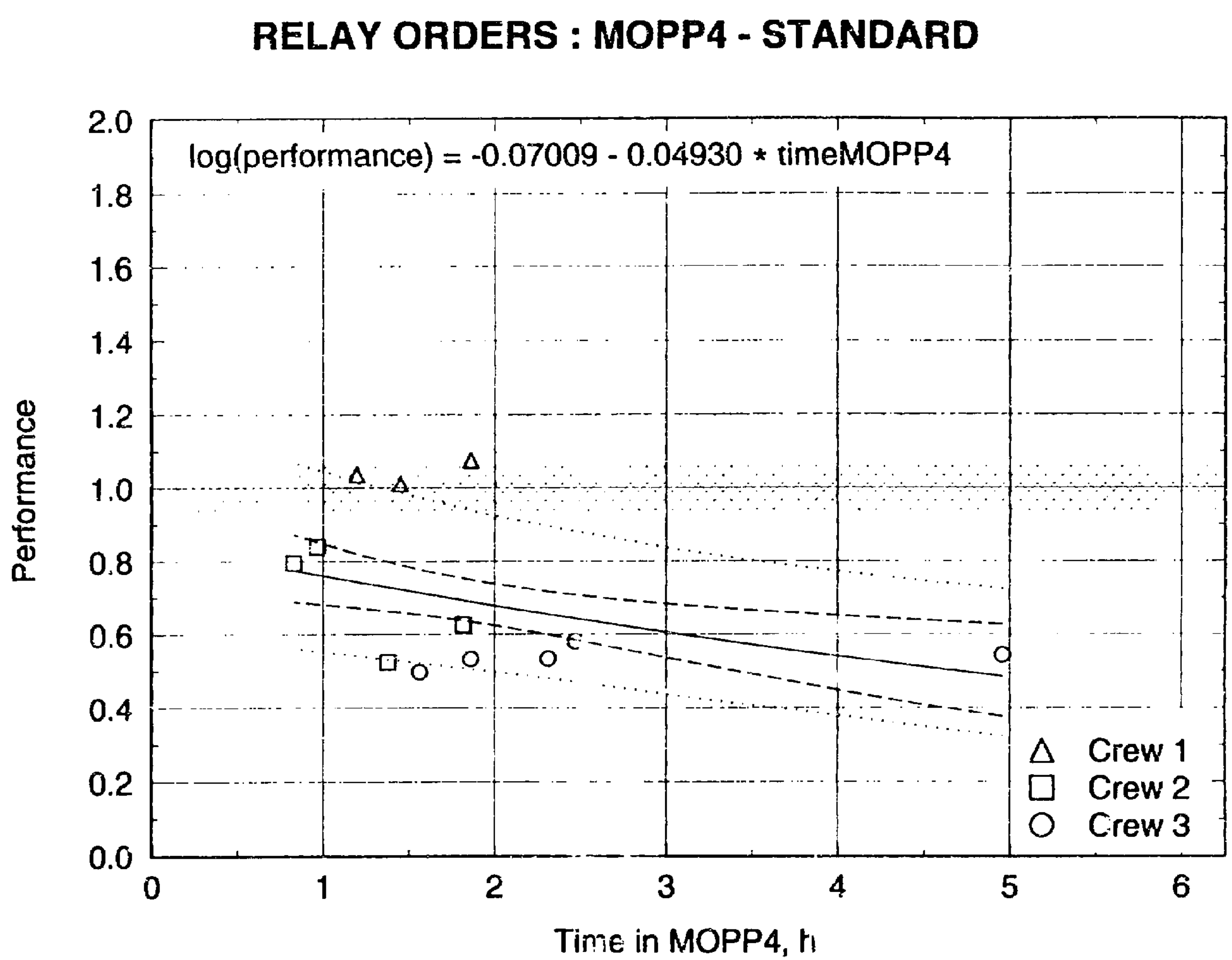


Figure 6-1. Performance vs time-in-MOPP4 with standard crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **relay orders.**

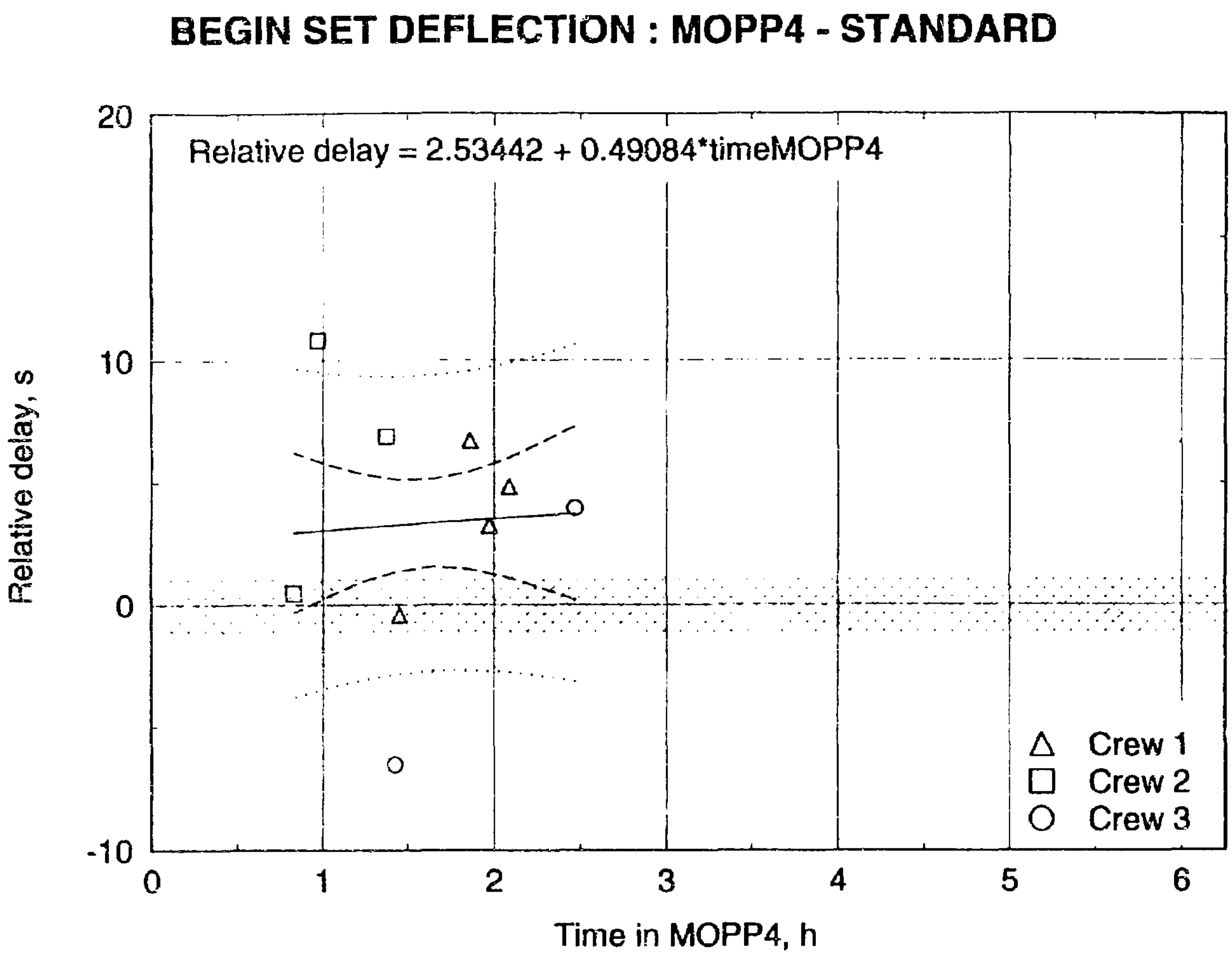


Figure 6-2. Performance vs time-in-MOPP4 with standard crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **begin set deflection.**

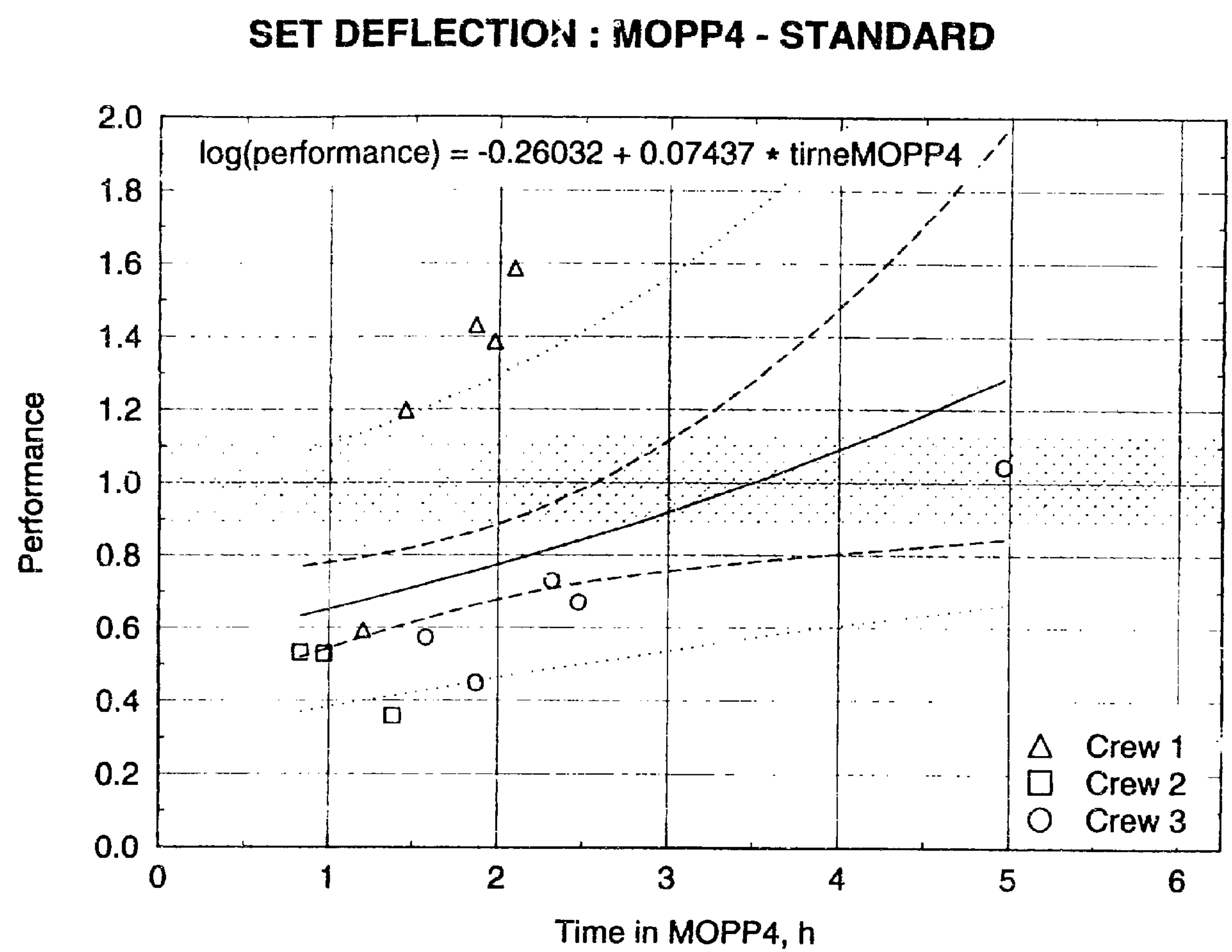


Figure 6-3. Performance vs time-in-MOPP4 with standard crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **set deflection.**

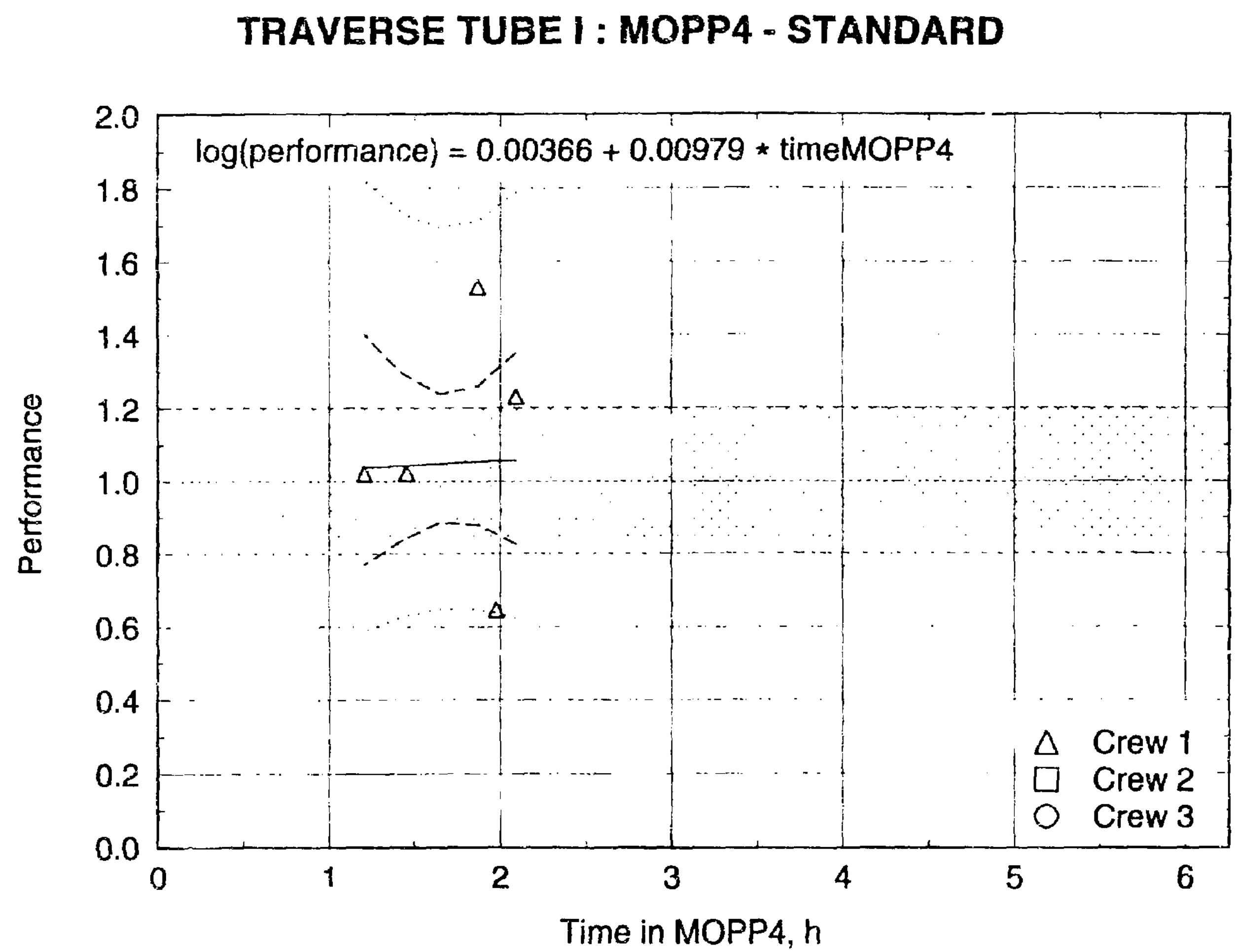


Figure 6-4. Performance vs time-in-MOPP4 with standard crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **traverse tube I.**

TRAVERSE TUBE II : MOPP4 - STANDARD

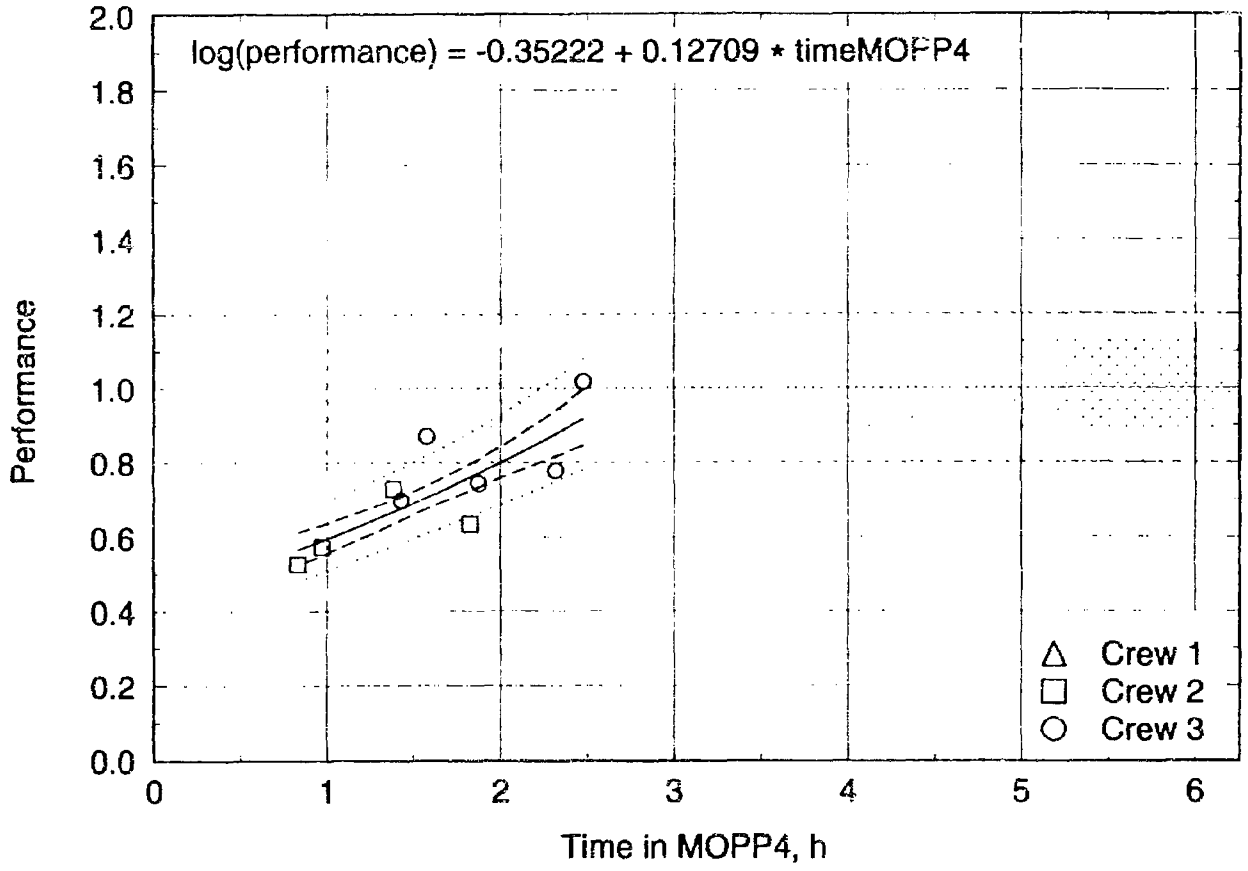


Figure 6-5. Performance vs time-in-MOPP4 with standard crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **traverse tube II.**

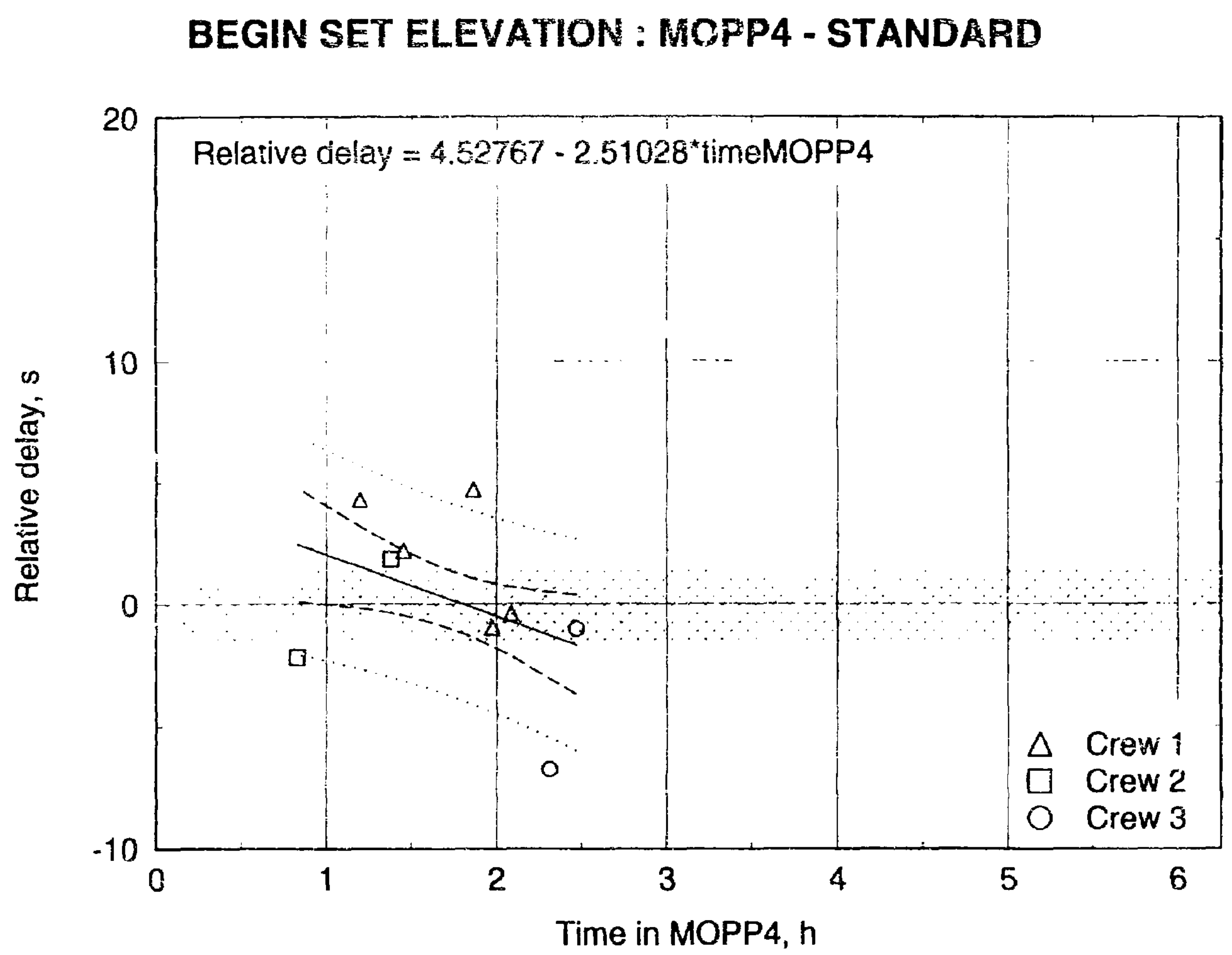


Figure 6-6. Performance vs time-in-MOPP4 with standard crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **begin set elevation.**

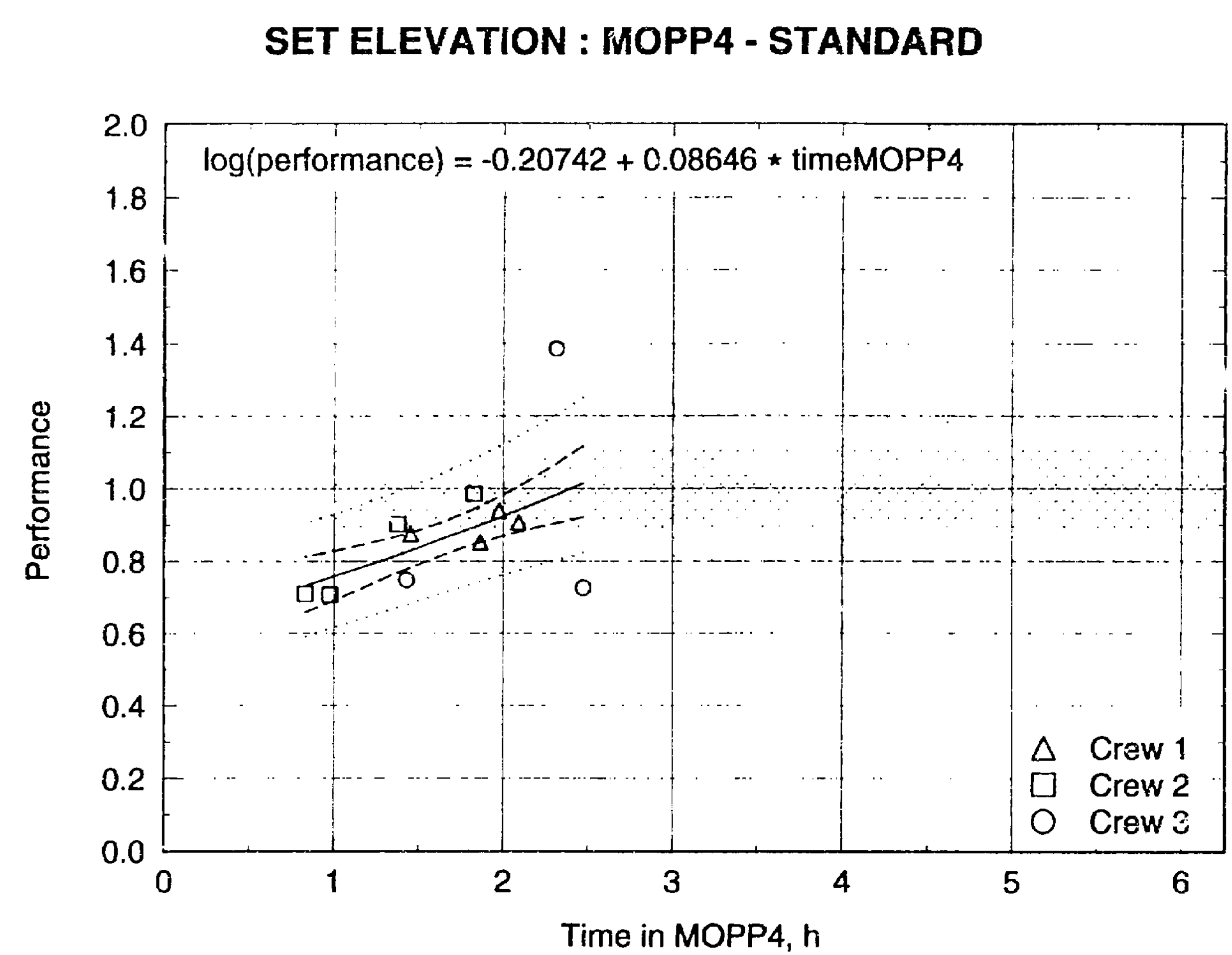


Figure 6-7. Performance vs time-in-MOPP4 with standard crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **set elevation.**

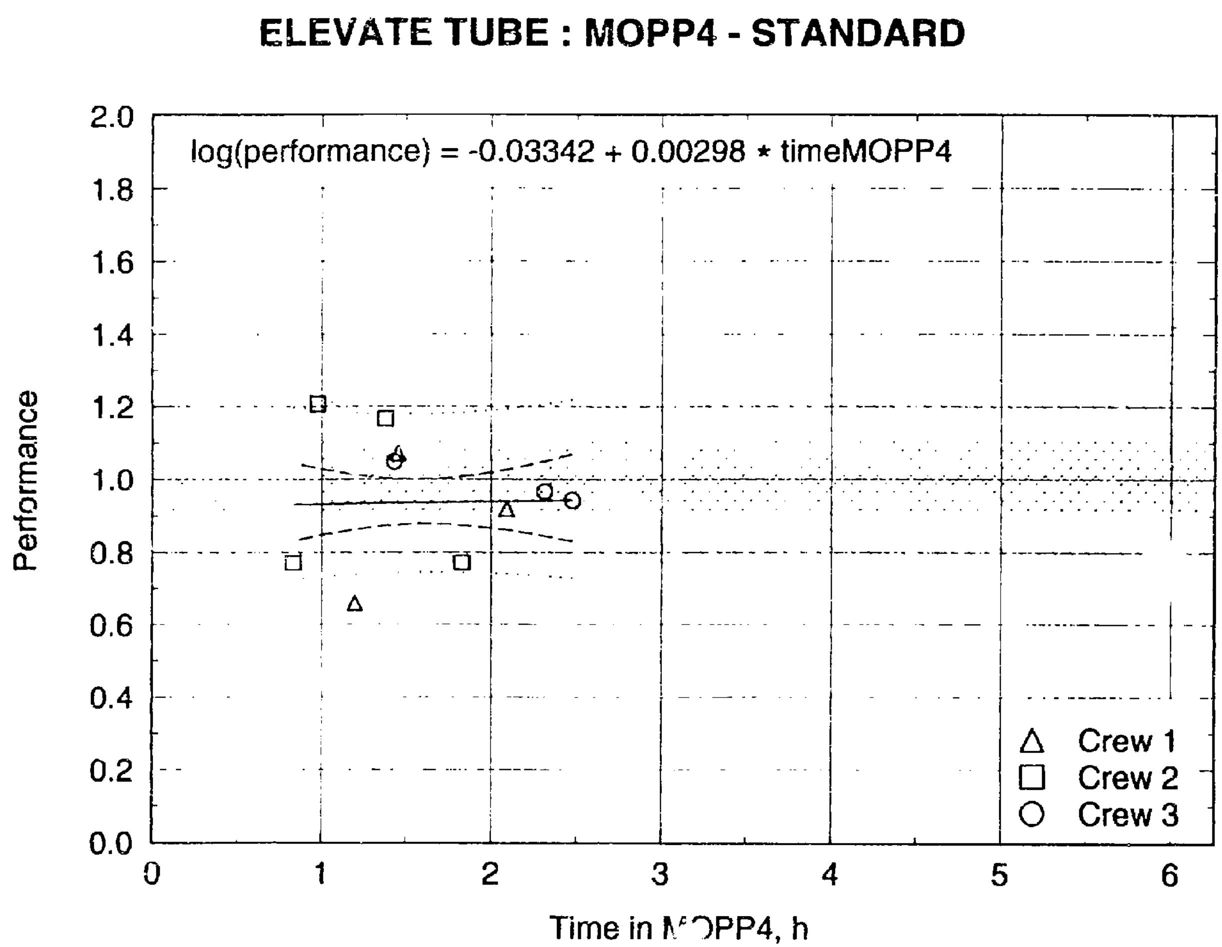


Figure 6-8. Performance vs time-in-MOPP4 with standard crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **elevate tube.**

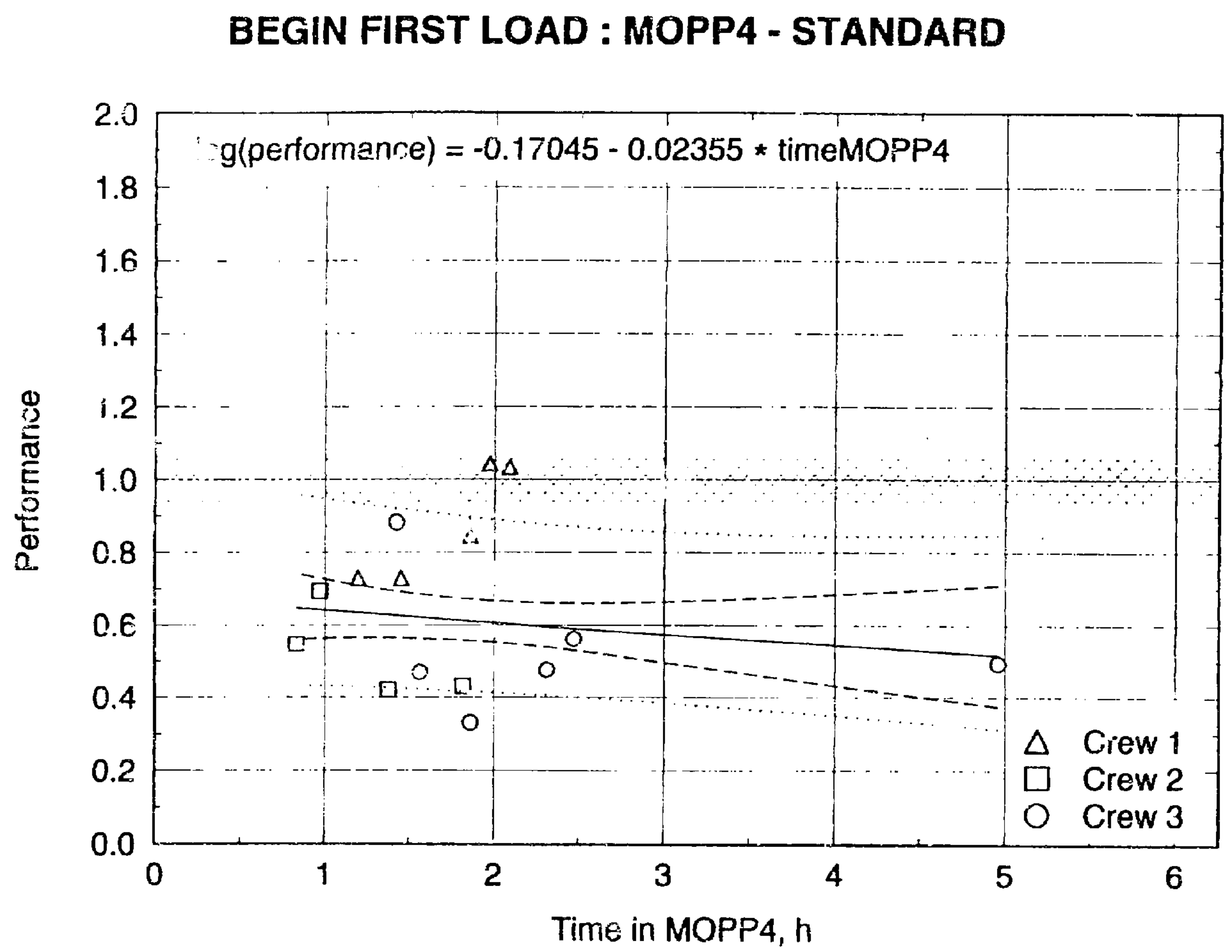


Figure 6-9. Performance vs time-in-MOPP4 with standard crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **begin first load.**

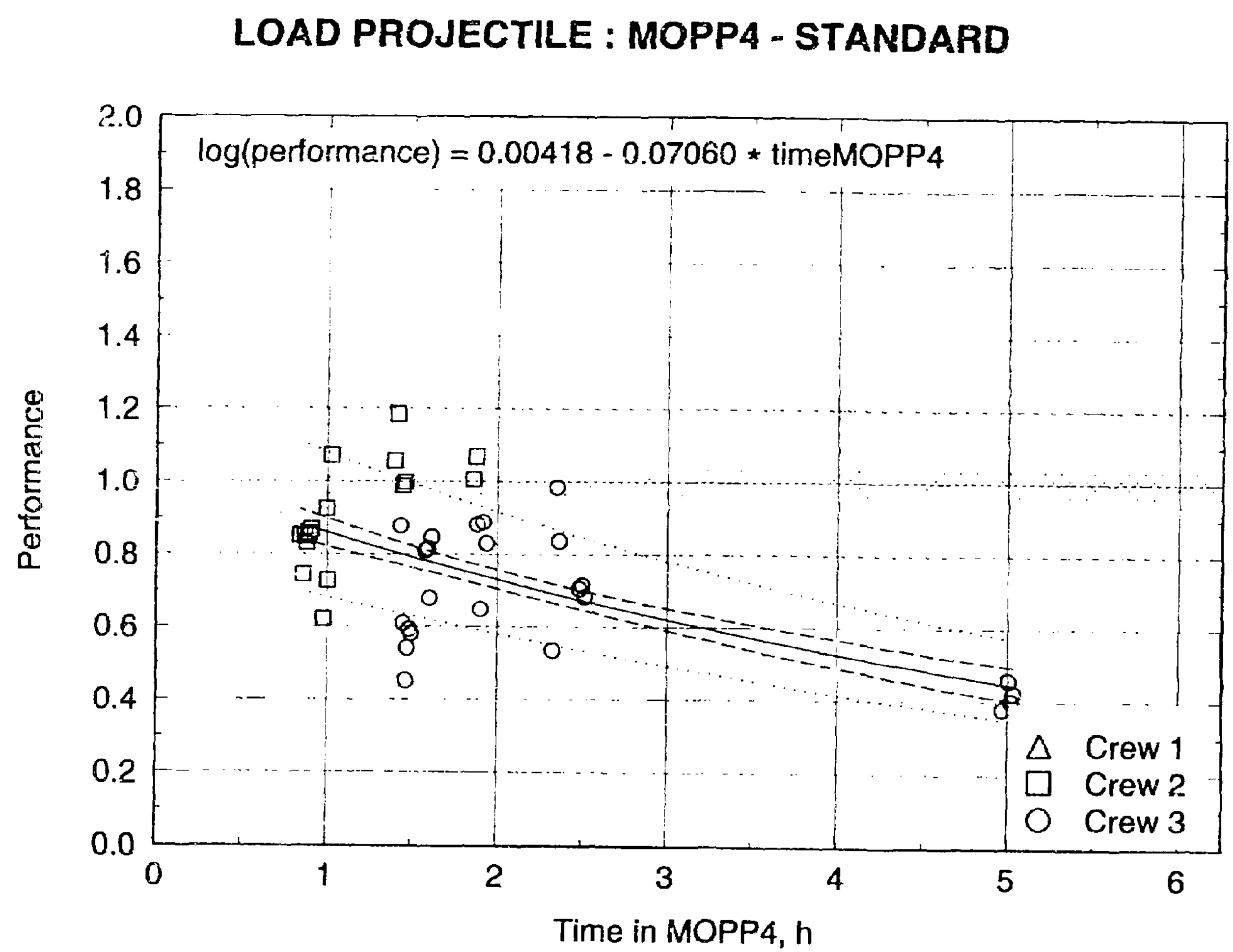


Figure 6-10. Performance vs time-in-MOPP4 with standard crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **load projectile.**

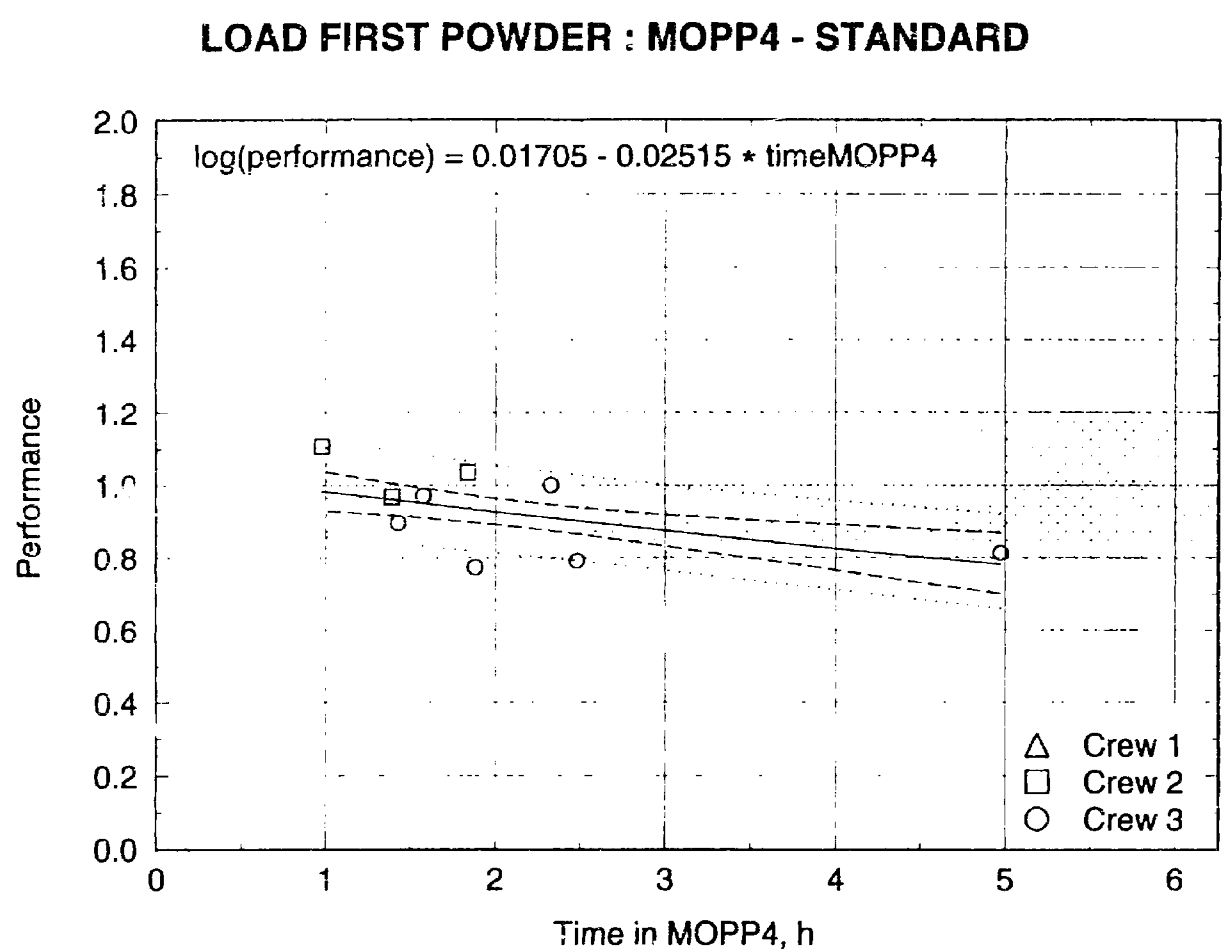


Figure 6-11. Performance vs time-in-MOPP4 with standard crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **load first powder.**

LOAD FIRST PROJO AND PWDR : MOPP4 - STANDARD

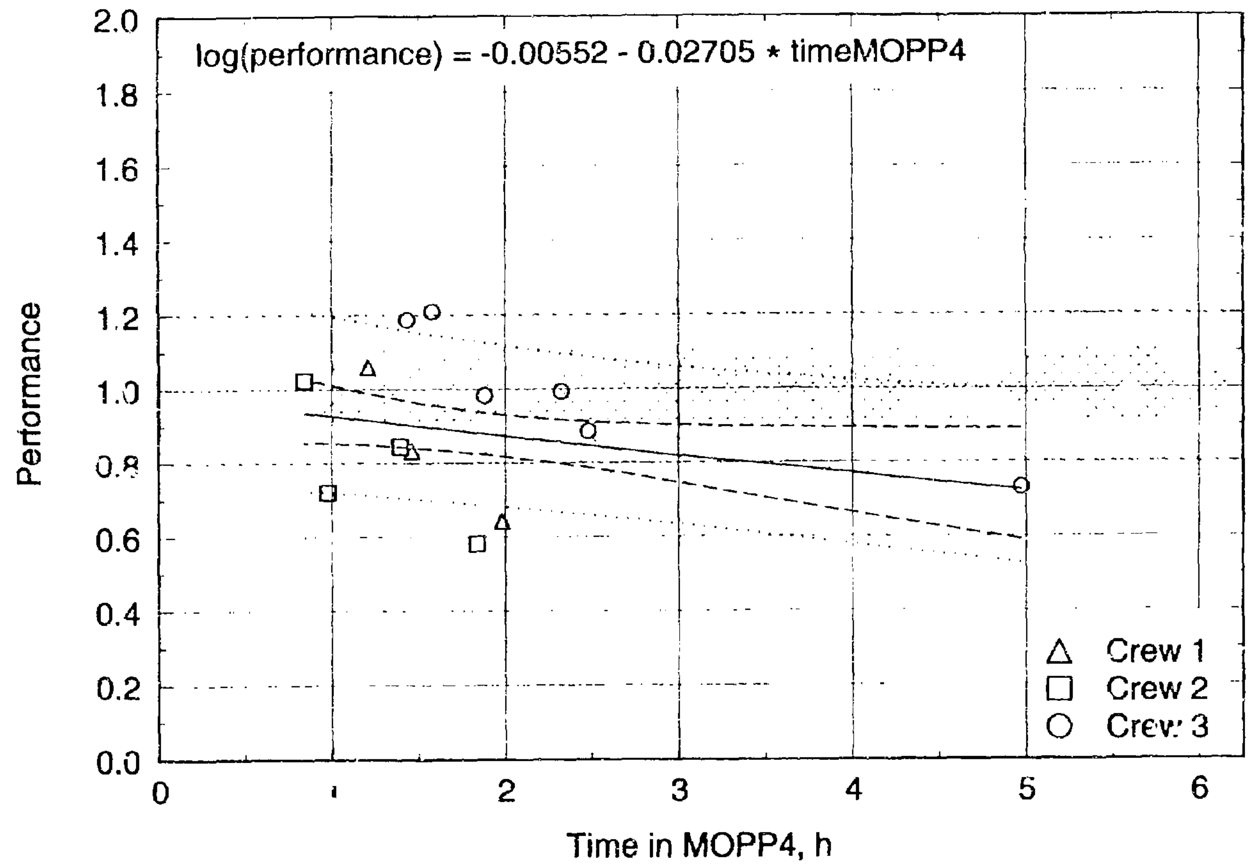


Figure 6-12. Performance vs time-in-MOPP4 with standard crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **load first projo and pwdr.**

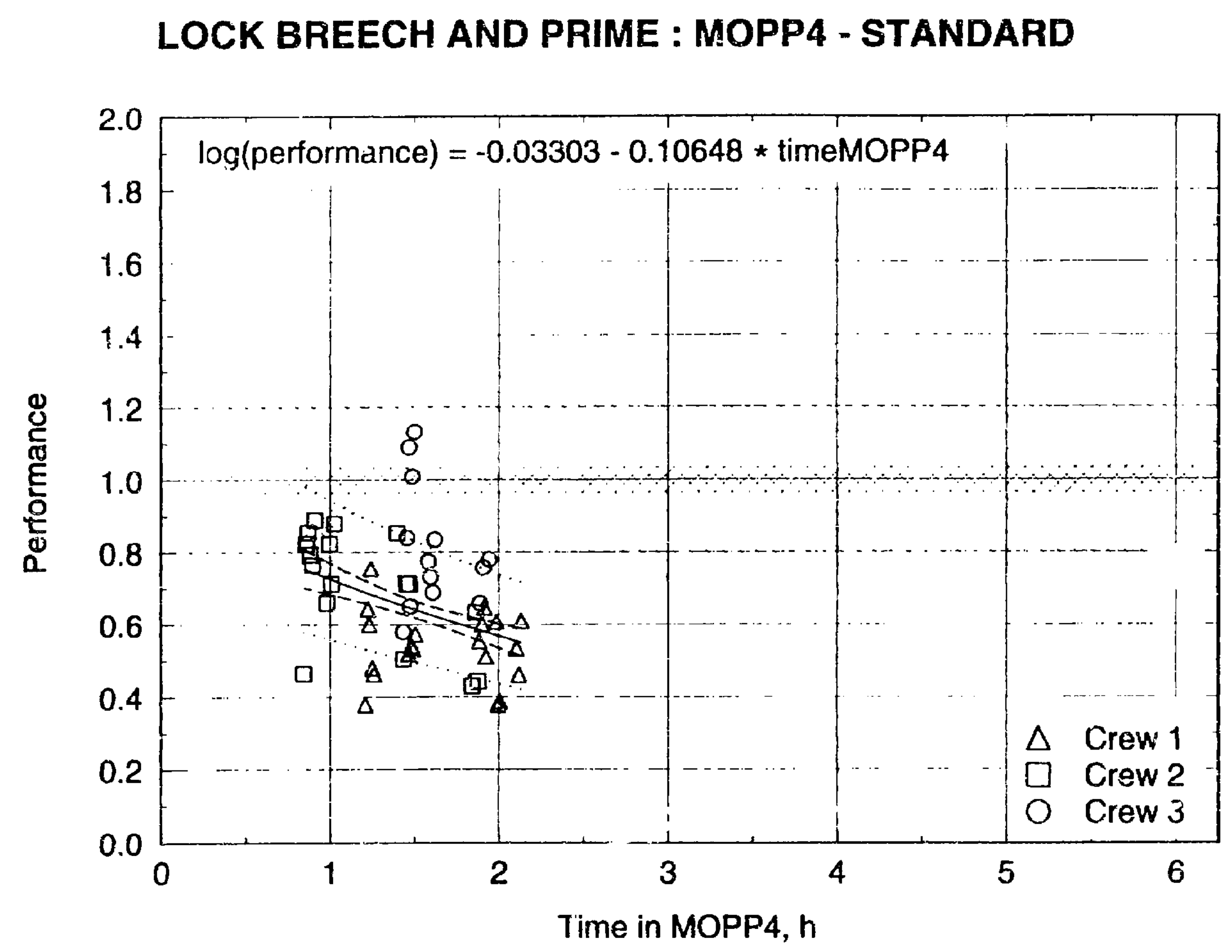


Figure 6-13. Performance vs time-in-MOPP4 with standard crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **lock breech and prime.**

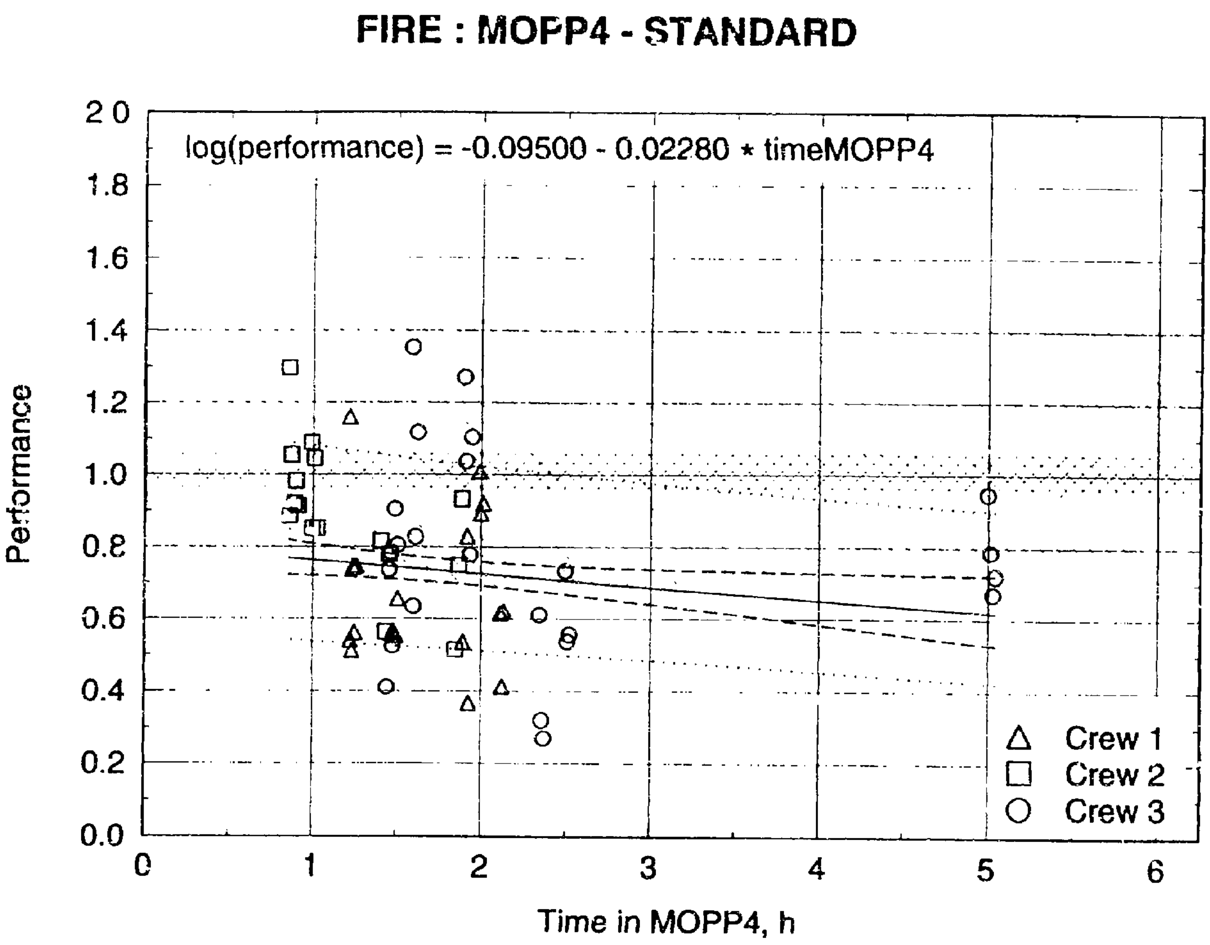


Figure 6-14. Performance vs time-in-MOPP4 with standard crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: fire.

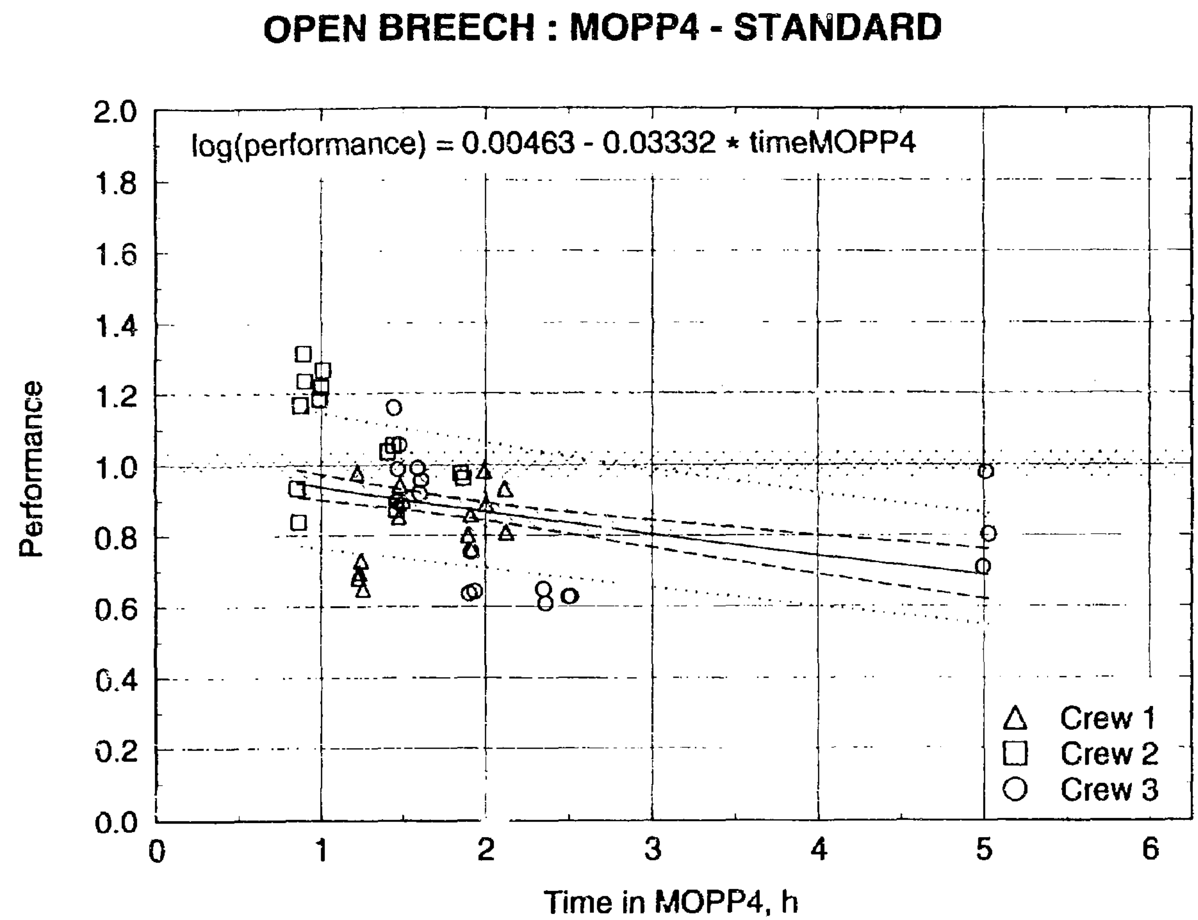


Figure 6-15. Performance vs time-in-MOPP4 with standard crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **open breech.**

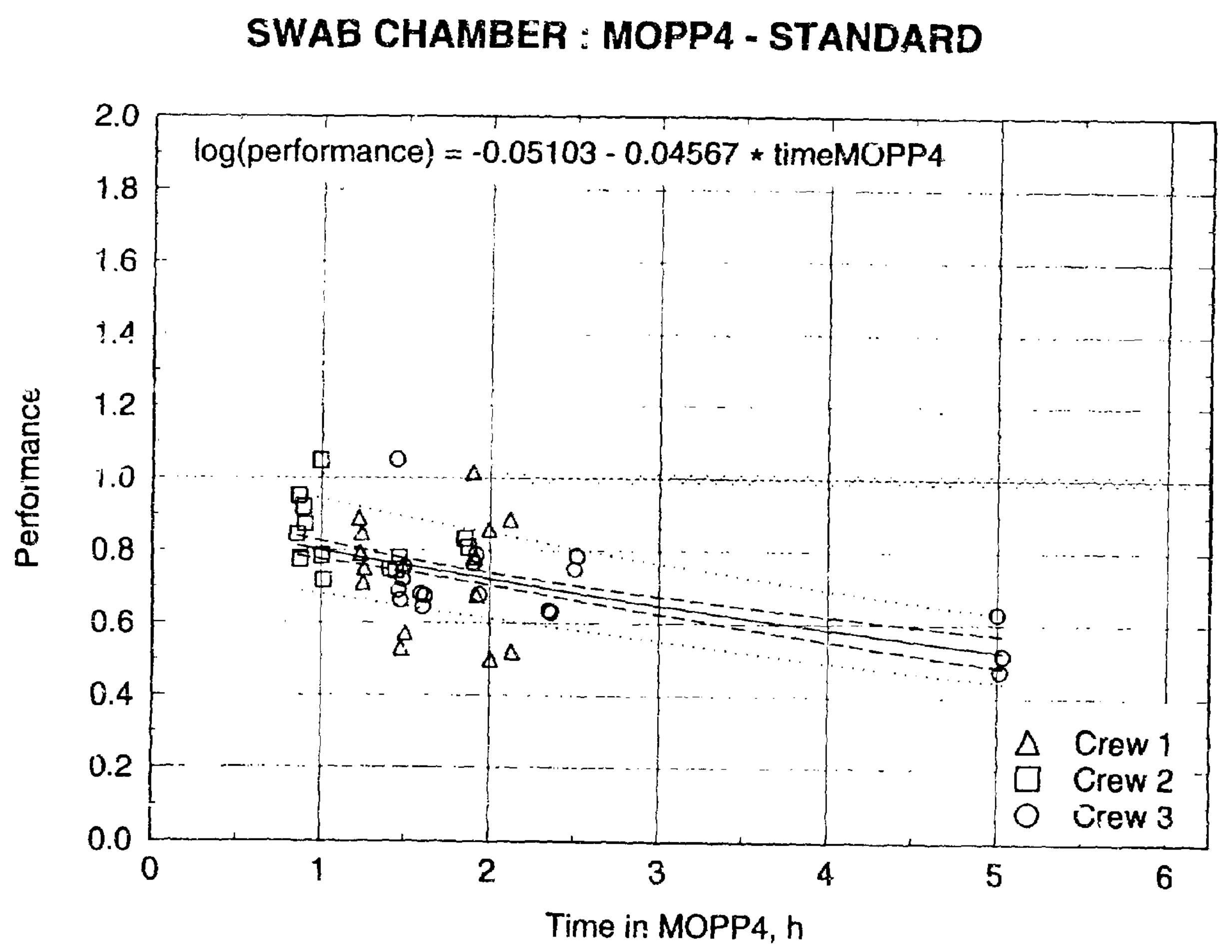


Figure 6-16. Performance vs time-in-MOPP4 with standard crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **swab chamber.**

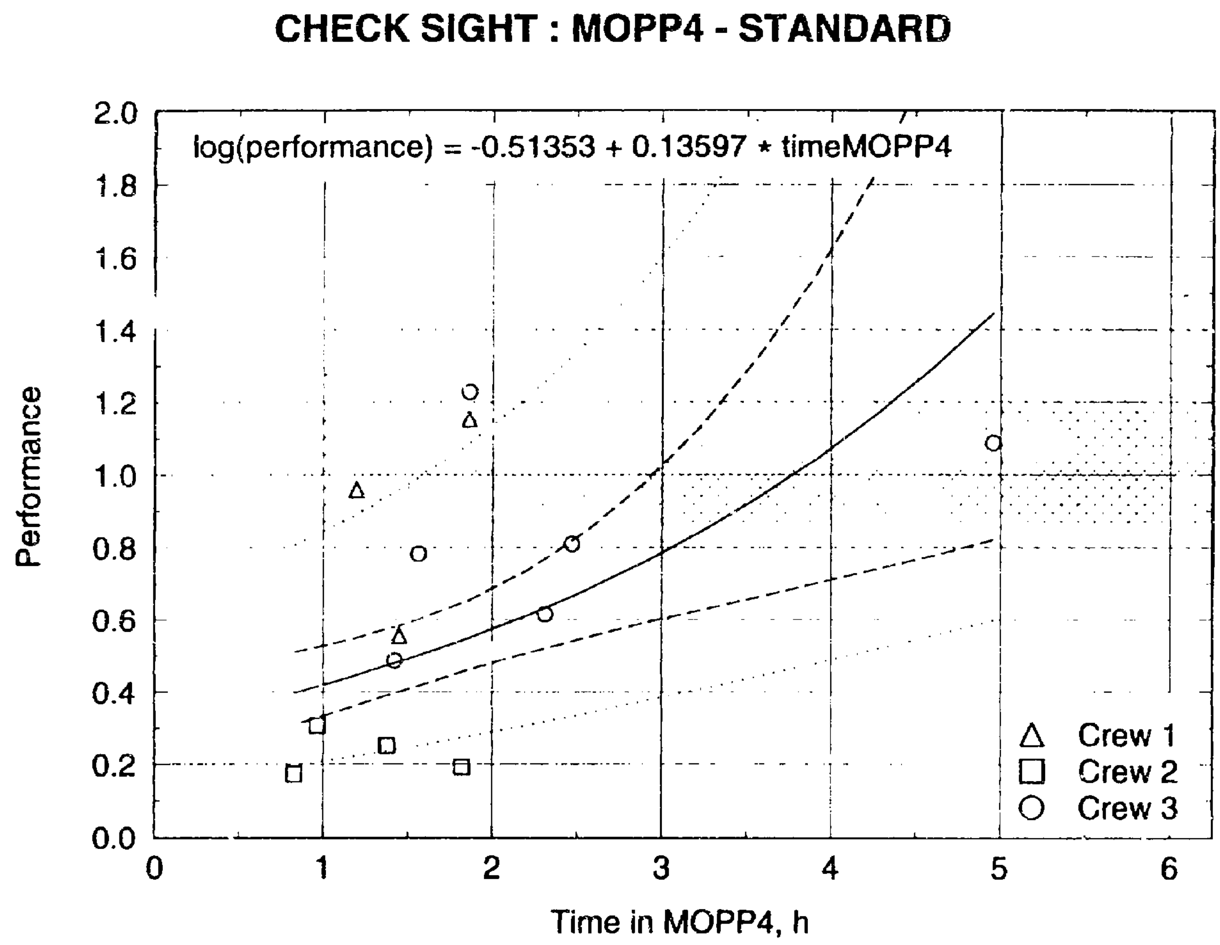


Figure 6-17. Performance vs time-in-MOPP4 with standard crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **check sight.**

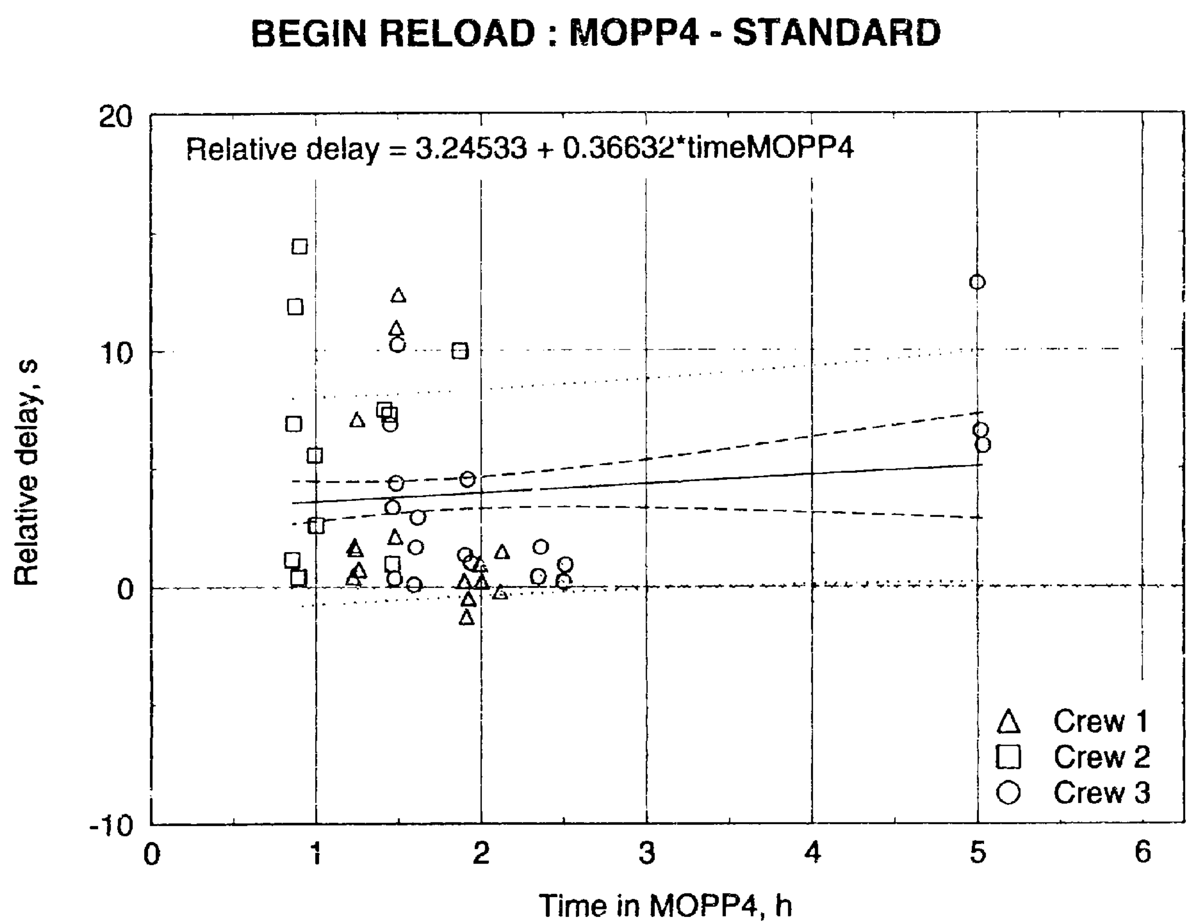


Figure 6-18. Performance vs time-in-MOPP4 with standard crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **begin reload.**

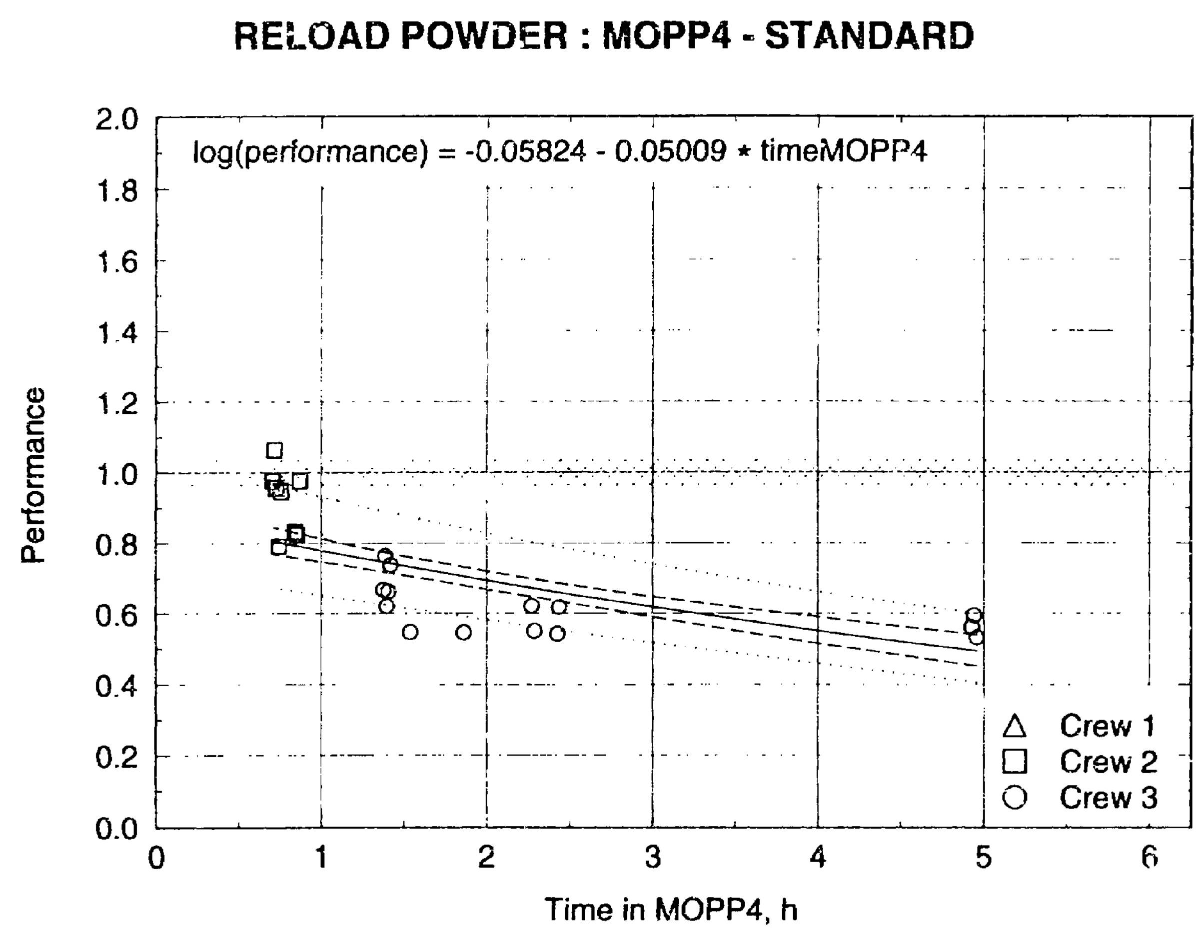


Figure 6-19. Performance vs time-in-MOPP4 with standard crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **reload powder.**

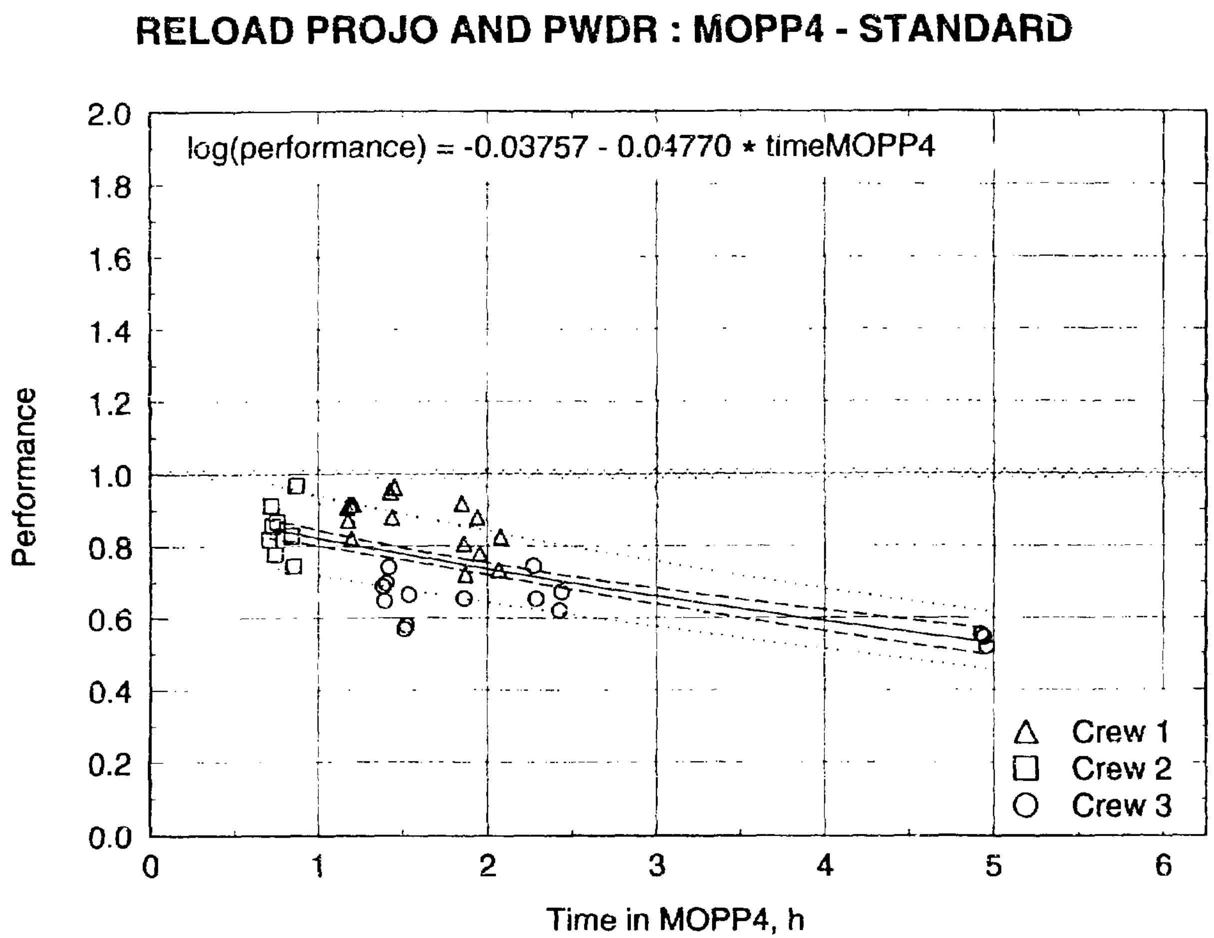


Figure 6-20. Performance vs time-in-MOPP4 with standard crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **reload projo and pwdr.**

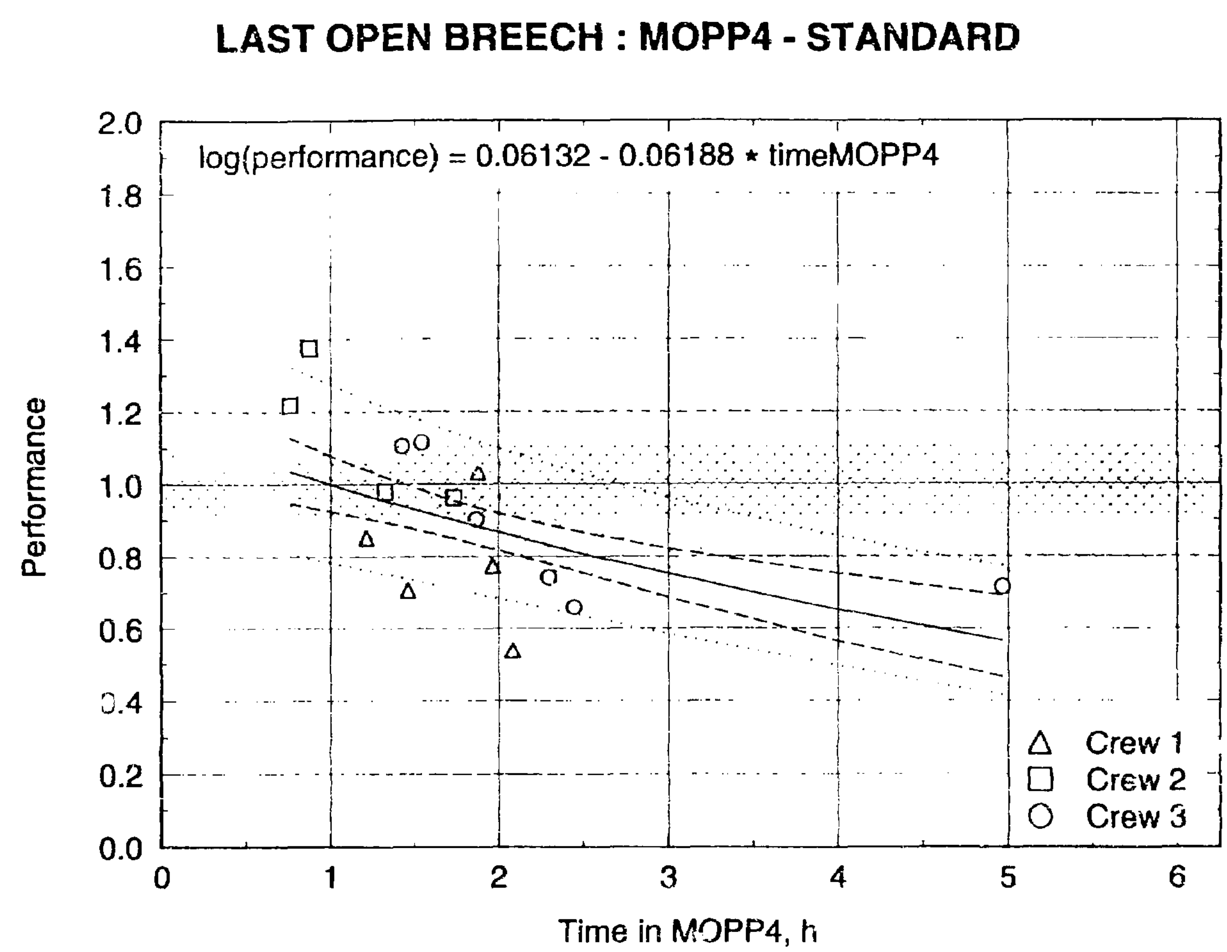


Figure 6-21. Performance vs time-in-MOPP4 with standard crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **last open breech.**

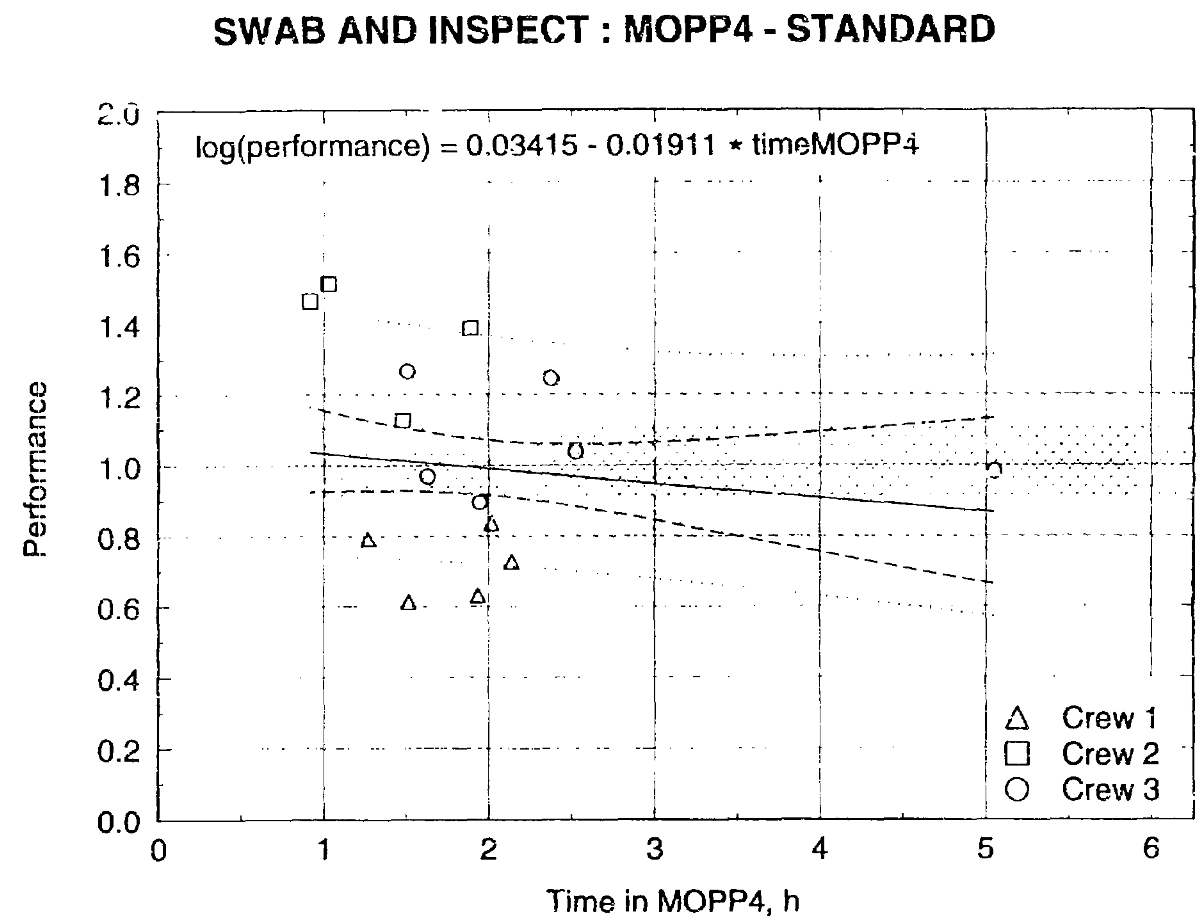


Figure 6-22. Performance vs time-in-MOPP4 with standard crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **swab and inspect.**

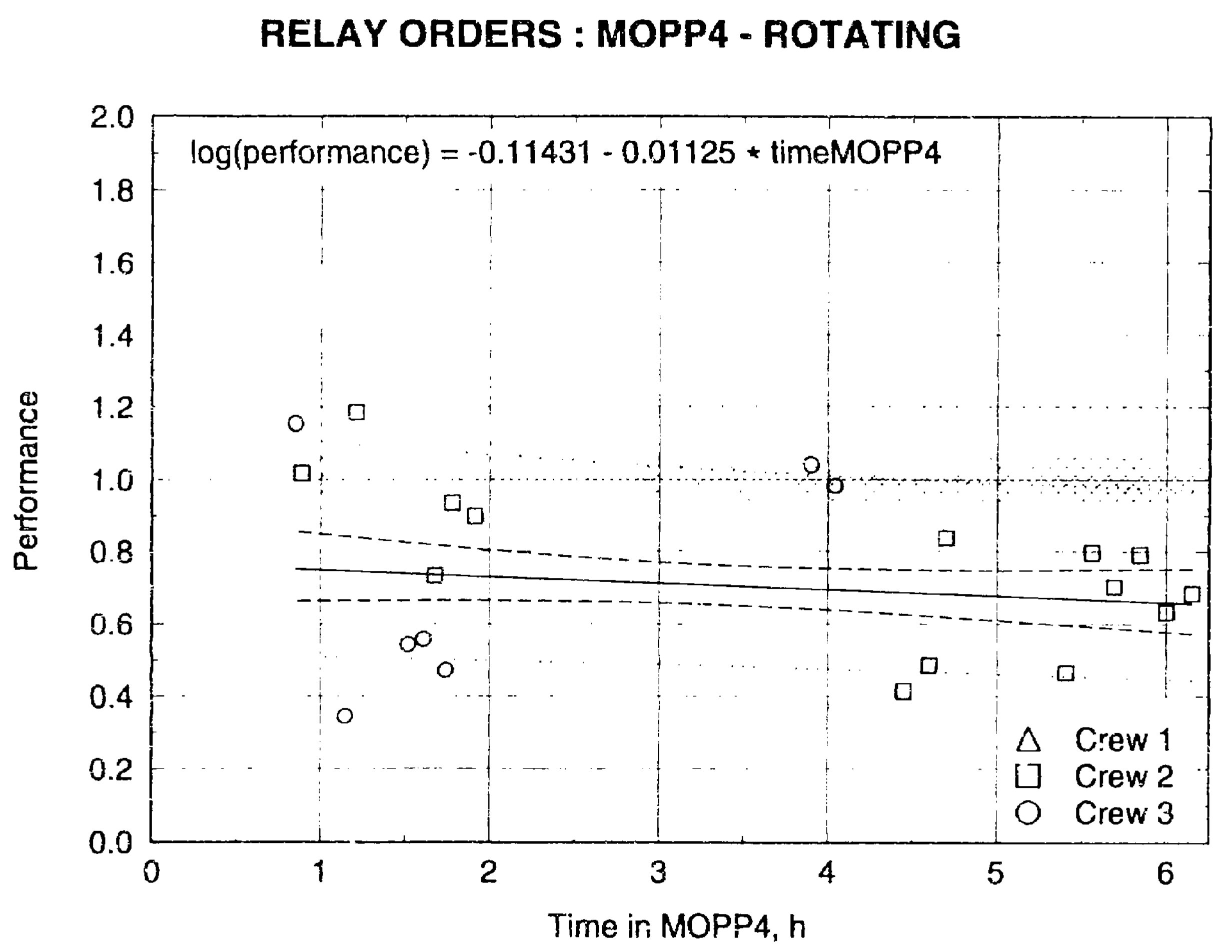


Figure 6-23. Performance vs time-in-MOPP4 with rotating crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **relay orders.**

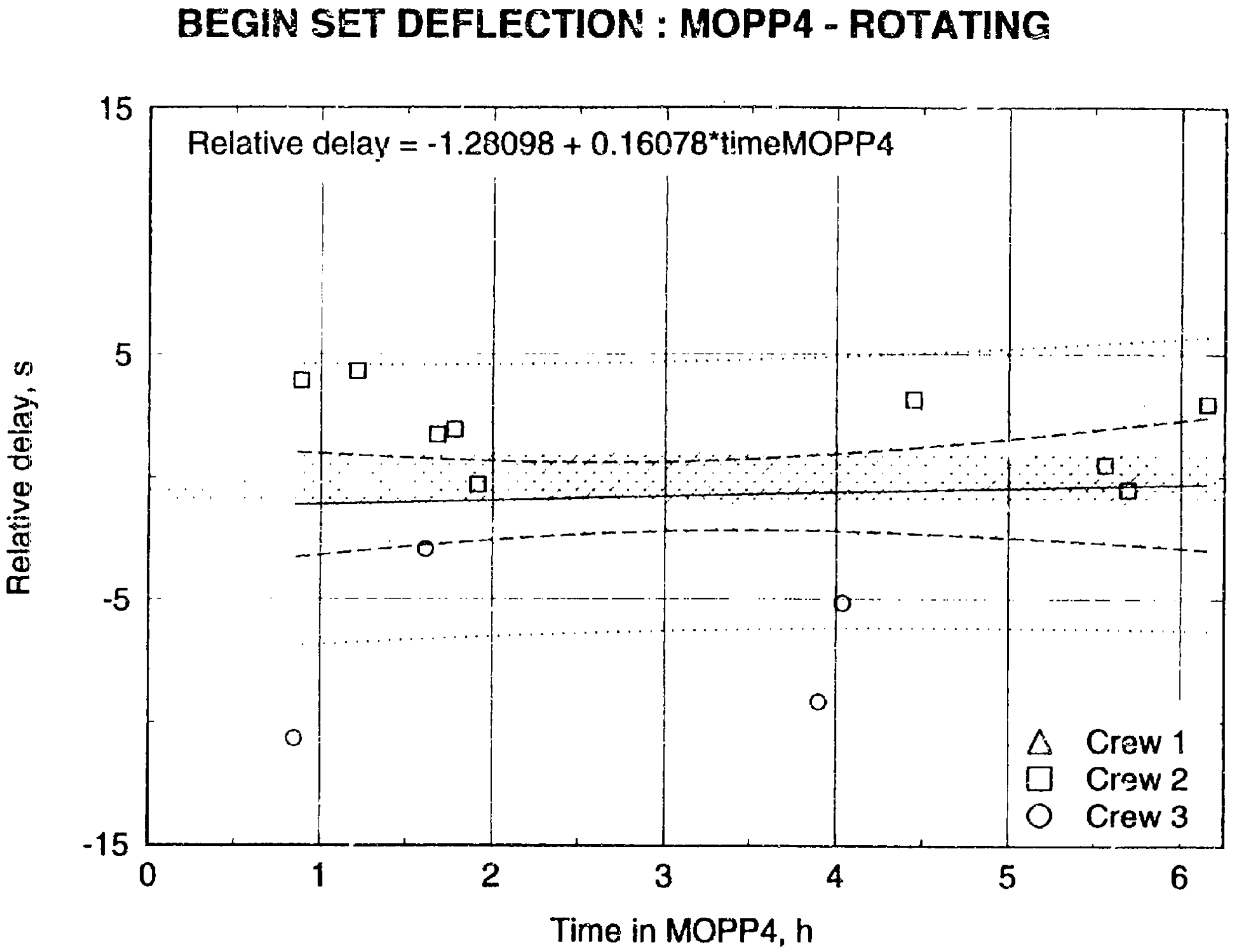


Figure 6-24. Performance vs time-in-MOPP4 with rotating crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **begin set deflection.**

SET DEFLECTION : MOPP4 - ROTATING

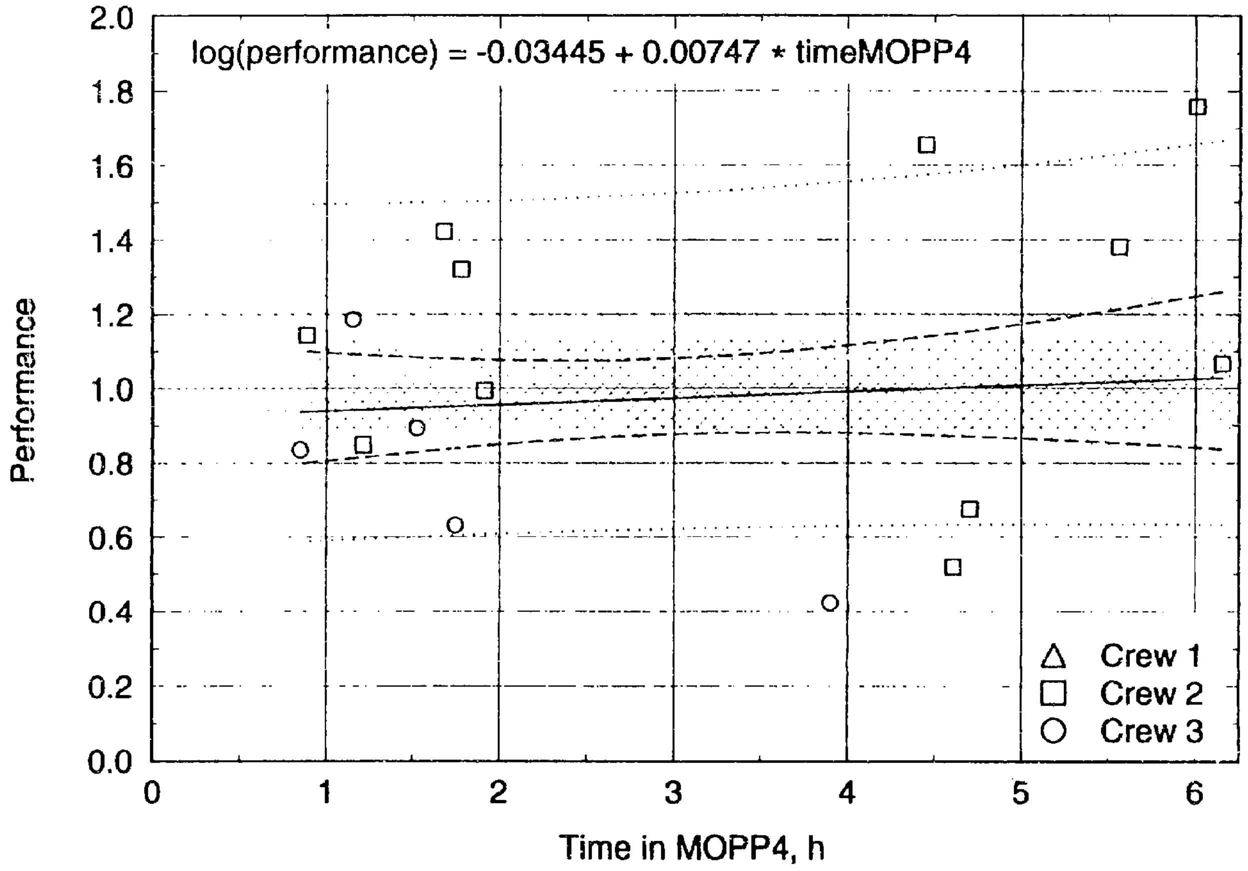


Figure 6-25. Performance vs time-in-MOPP4 with rotating crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **set deflection.**

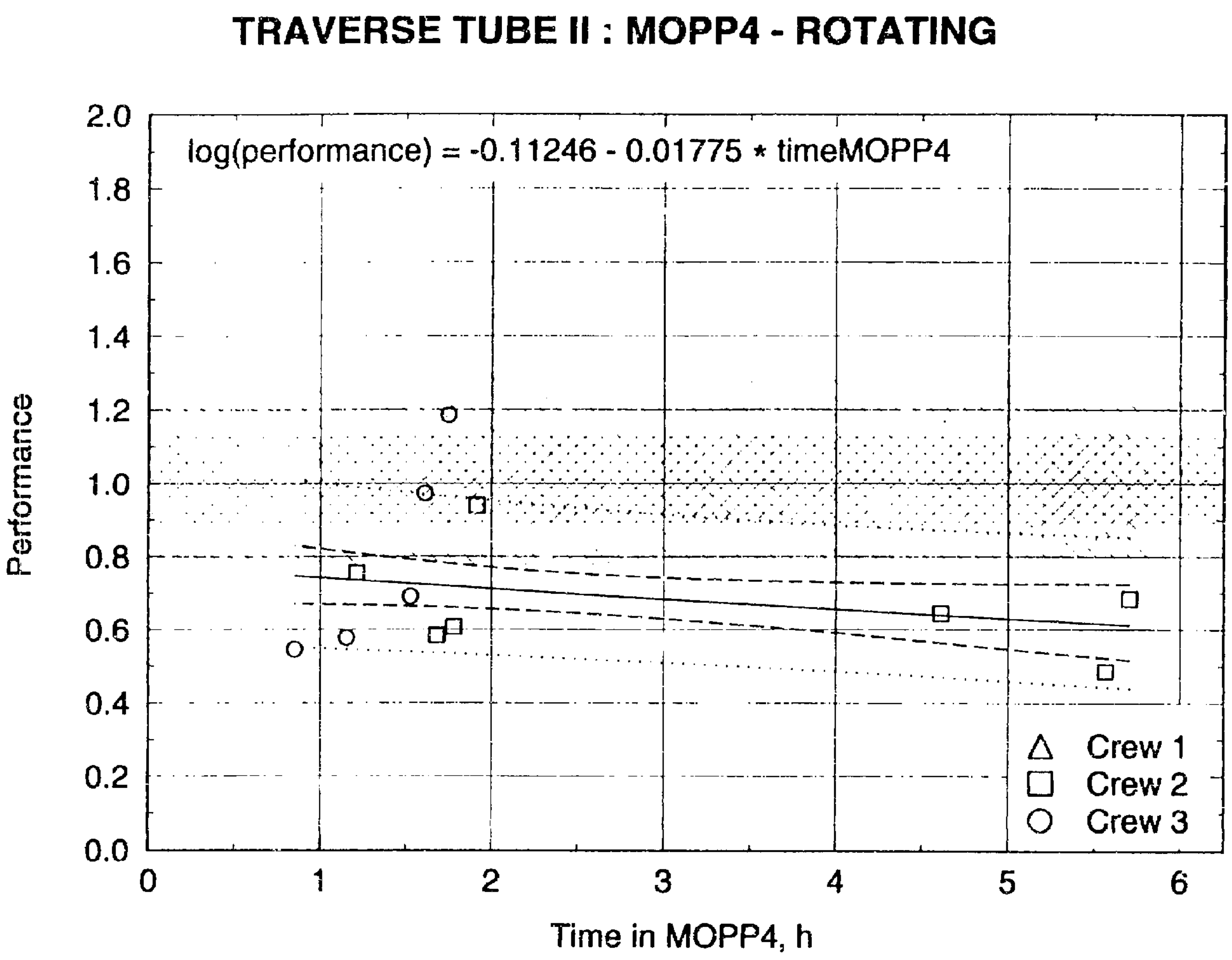


Figure 6-26. Performance vs time-in-MOPP4 with rotating crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **traverse tube II.**

BEGIN SET ELEVATION : MOPP4 - ROTATING

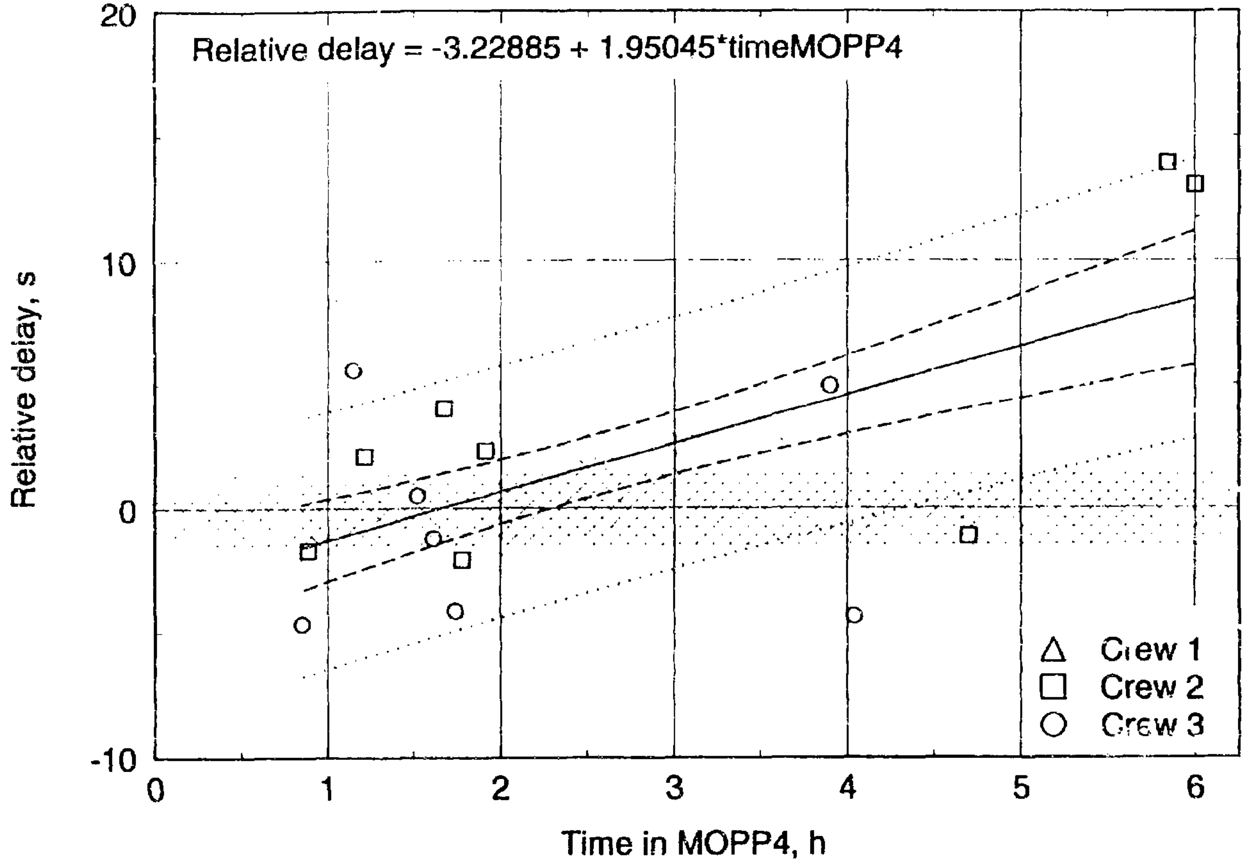


Figure 6-27. Performance vs time-in-MOPP4 with rotating crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **begin set elevation.**

SET ELEVATION : MOPP4 - ROTATING

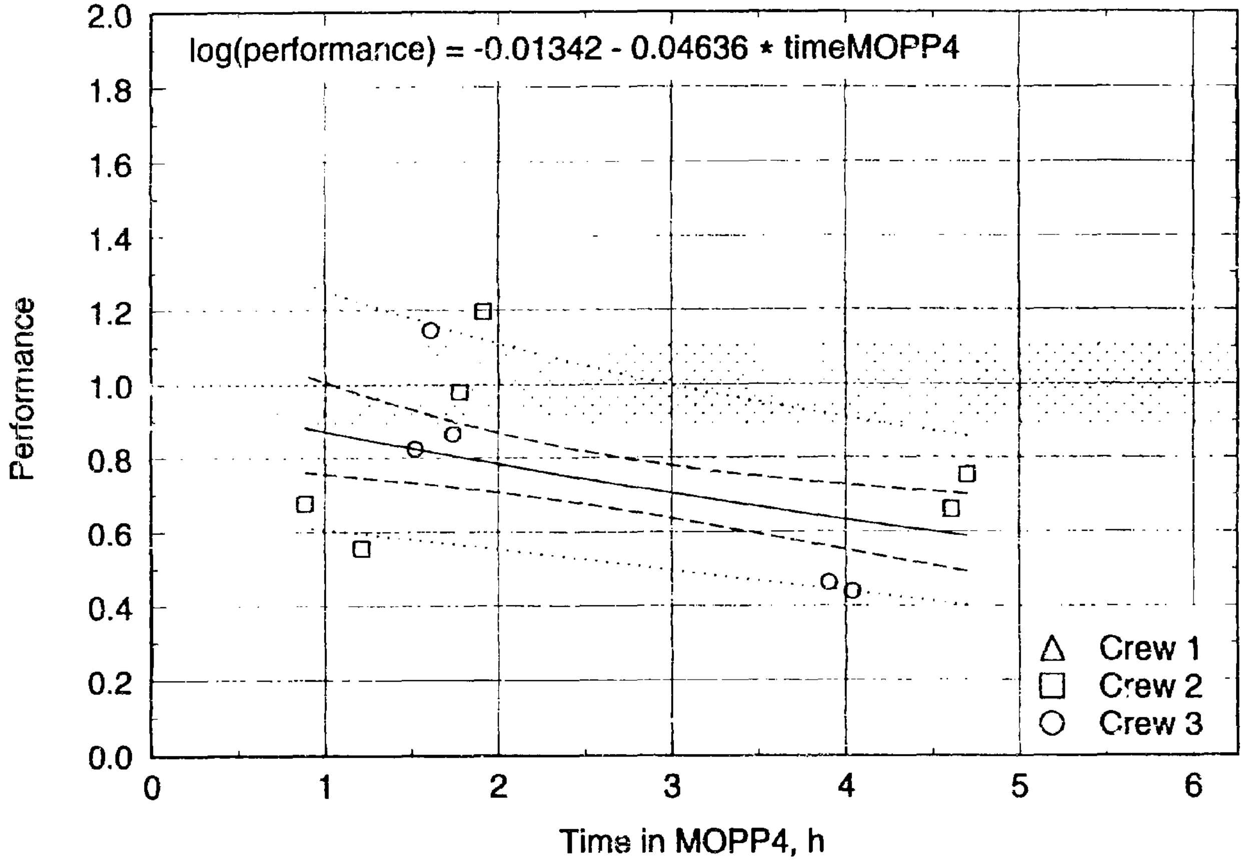


Figure 6-28. Performance vs time-in-MOPP4 with rotating crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **set elevation.**

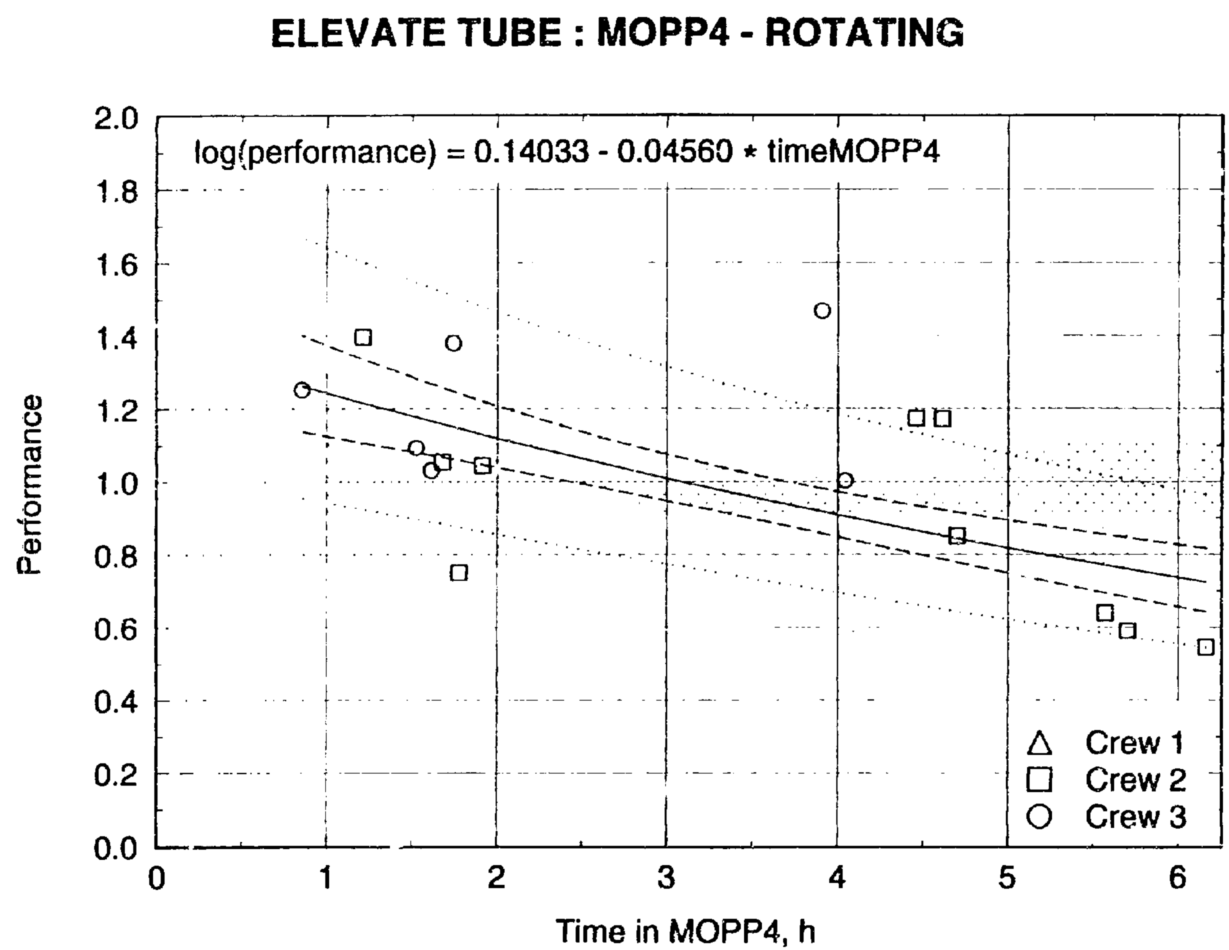


Figure 6-29. Performance vs time-in-MOPP4 with rotating crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **elevate tube.**

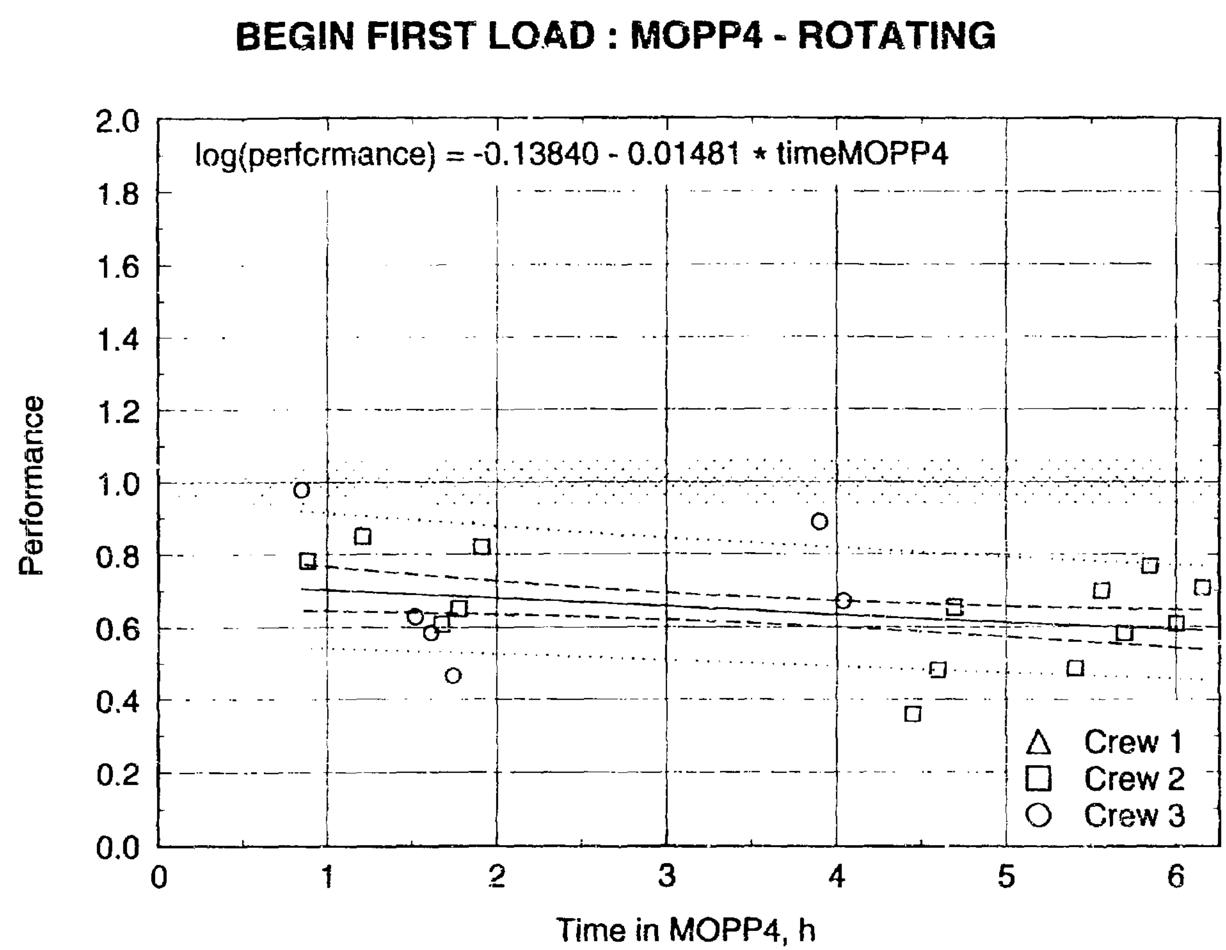


Figure 6-30. Performance vs time-in-MOPP4 with rotating crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **begin first load.**

LOAD PROJECTILE : MOPP4 - ROTATING

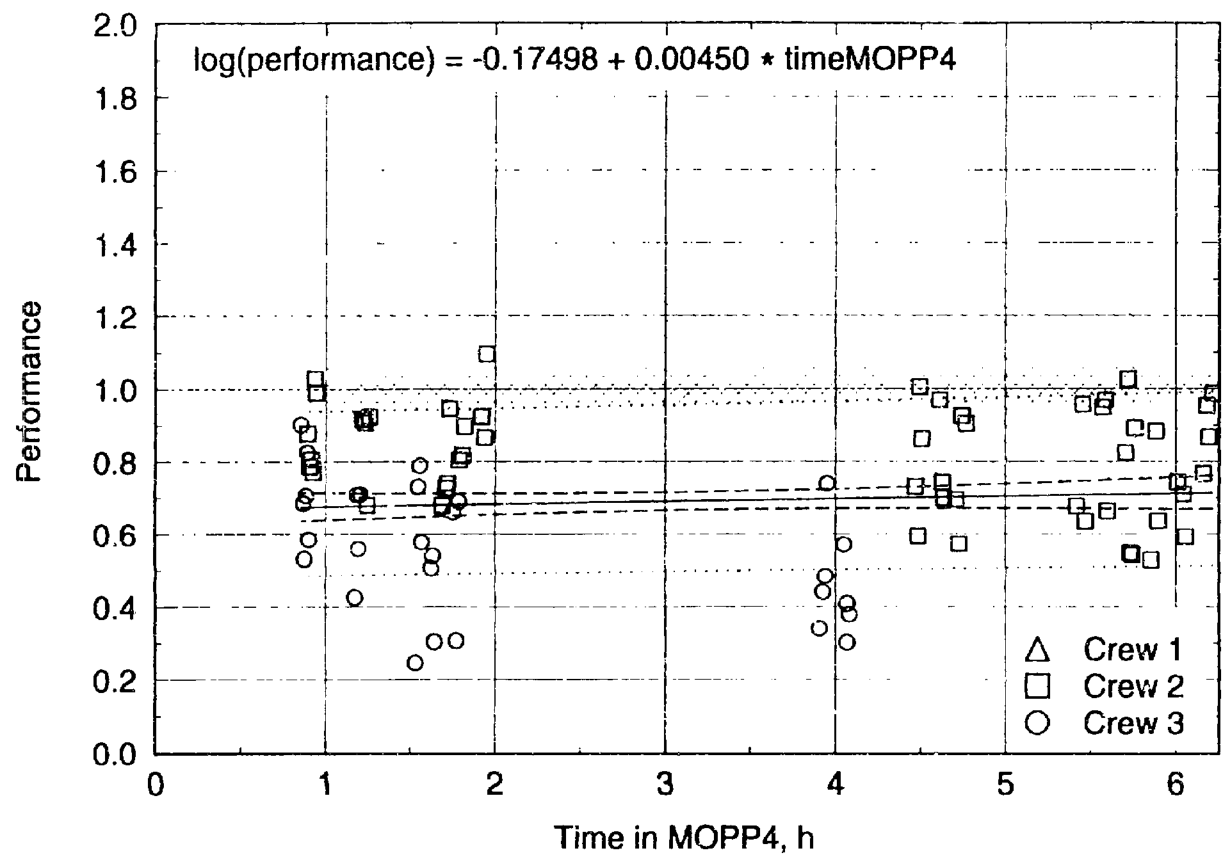


Figure 6-31. Performance vs time-in-MOPP4 with rotating crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **load projectile.**

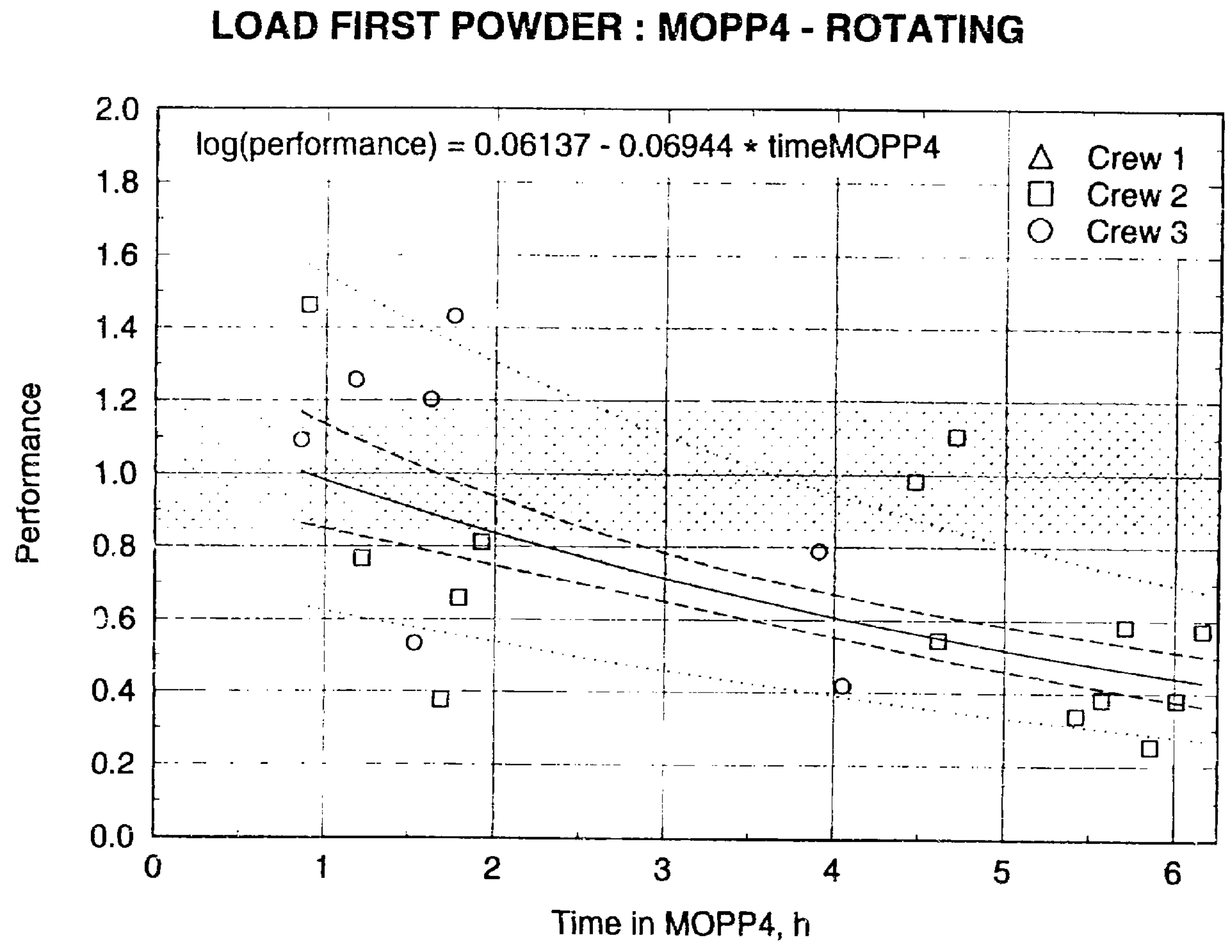


Figure 6-32. Performance vs time-in-MOPP4 with rotating crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **load first powder.**

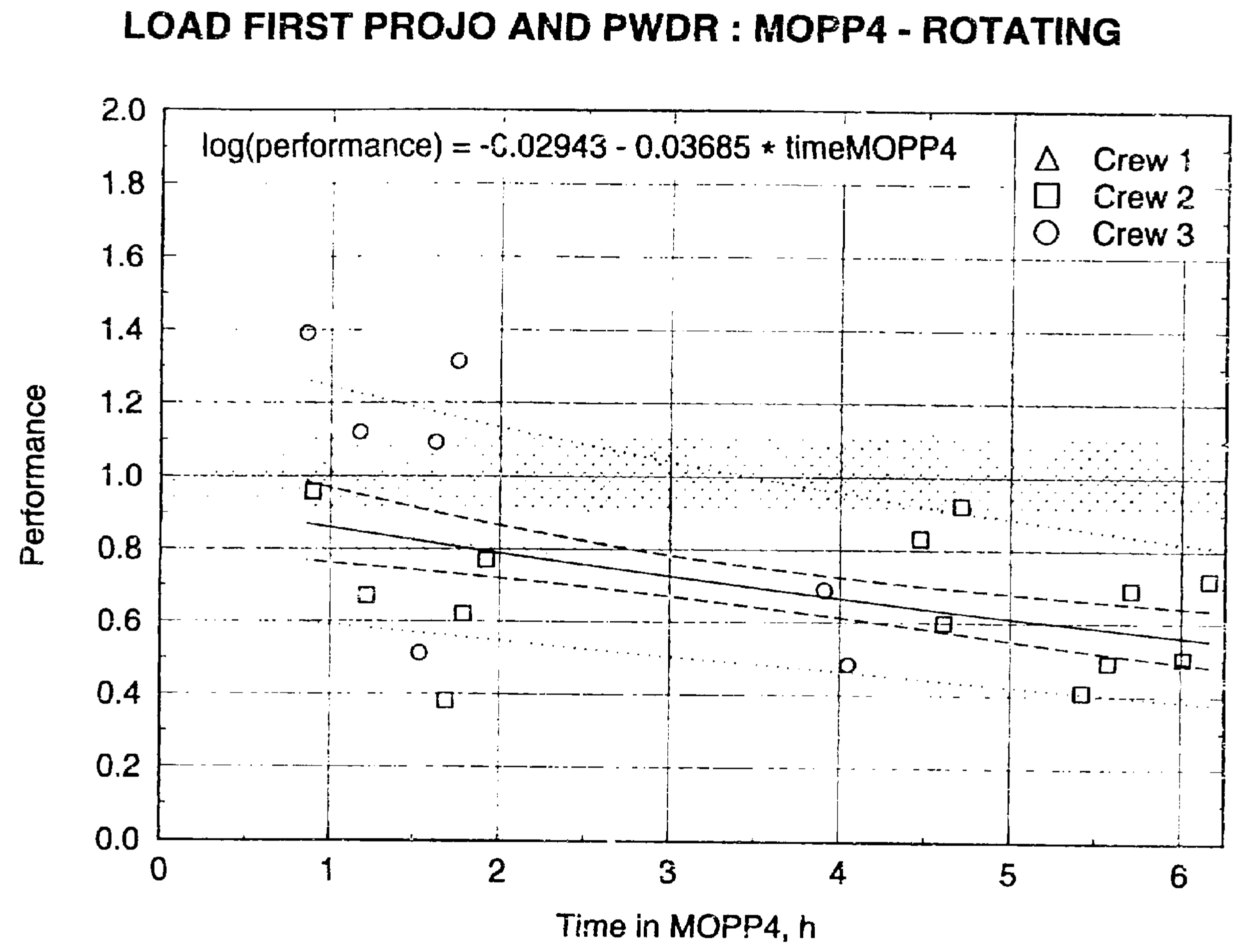


Figure 6-33. Performance vs time-in-MOPP4 with rotating crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **load first projo and pwdr.**

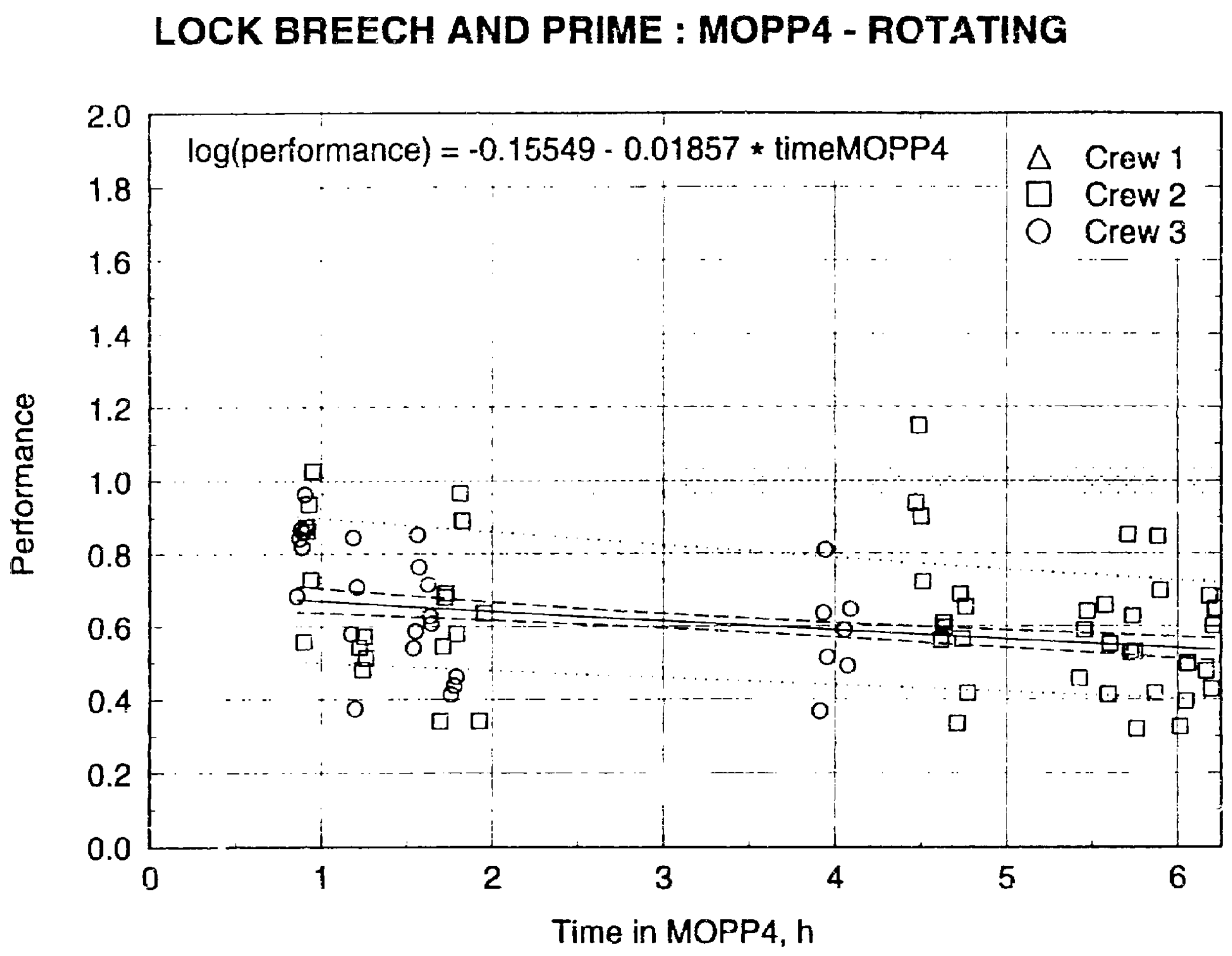


Figure 6-34. Performance vs time-in-MOPP4 with rotating crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **lock breech and prime.**

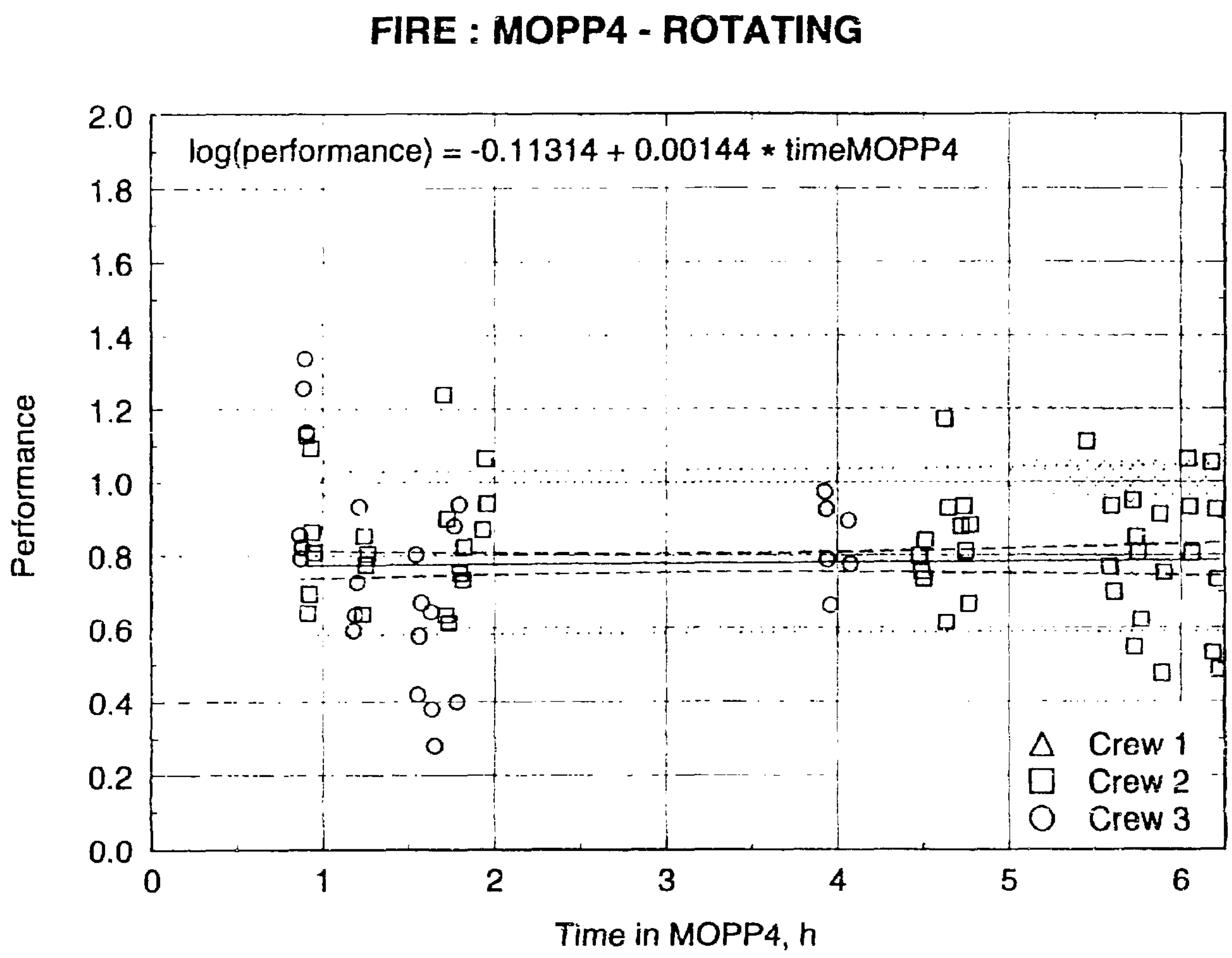


Figure 6-35. Performance vs time-in-MOPP4 with rotating crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **fire.**

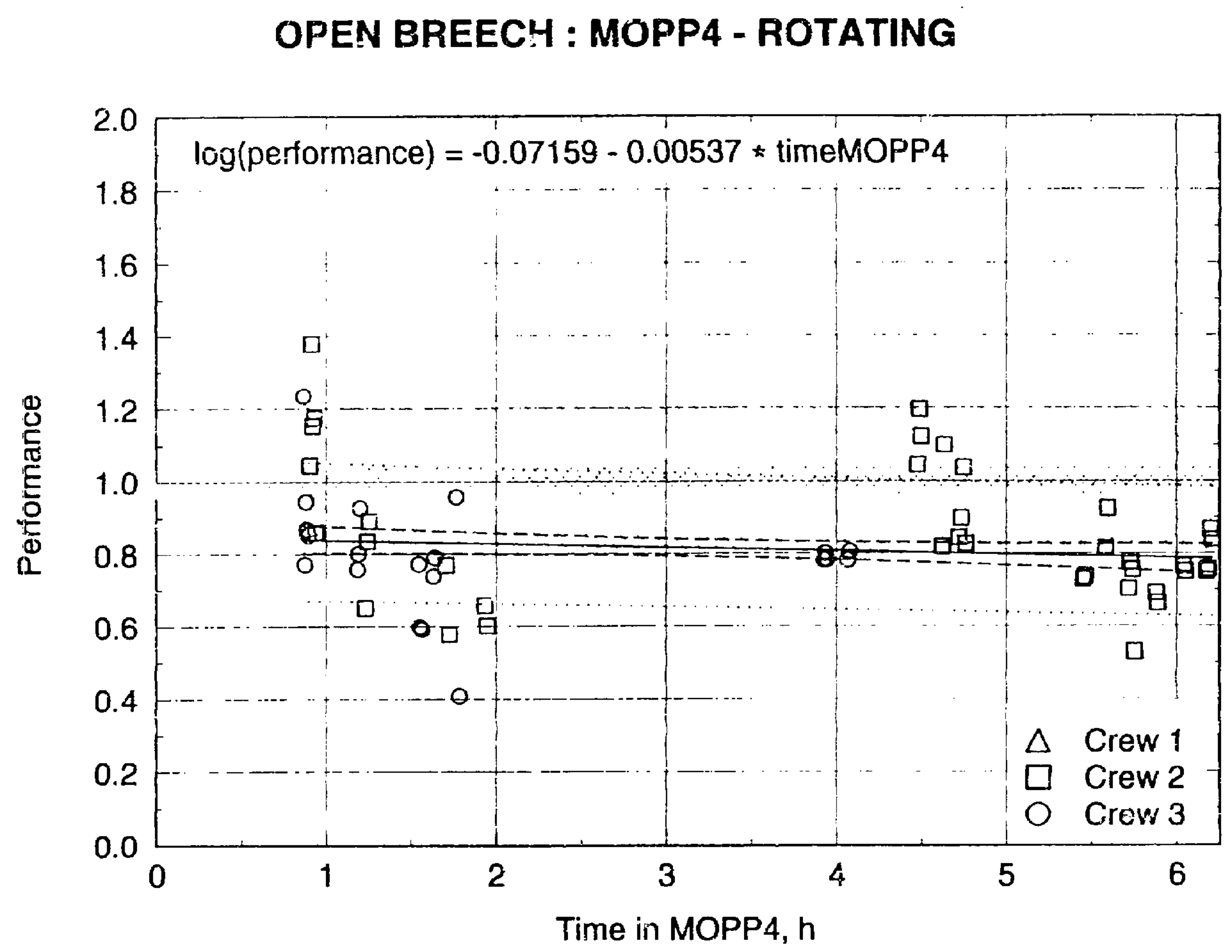


Figure 6-36. Performance vs time-in-MOPP4 with rotating crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **open breech.**

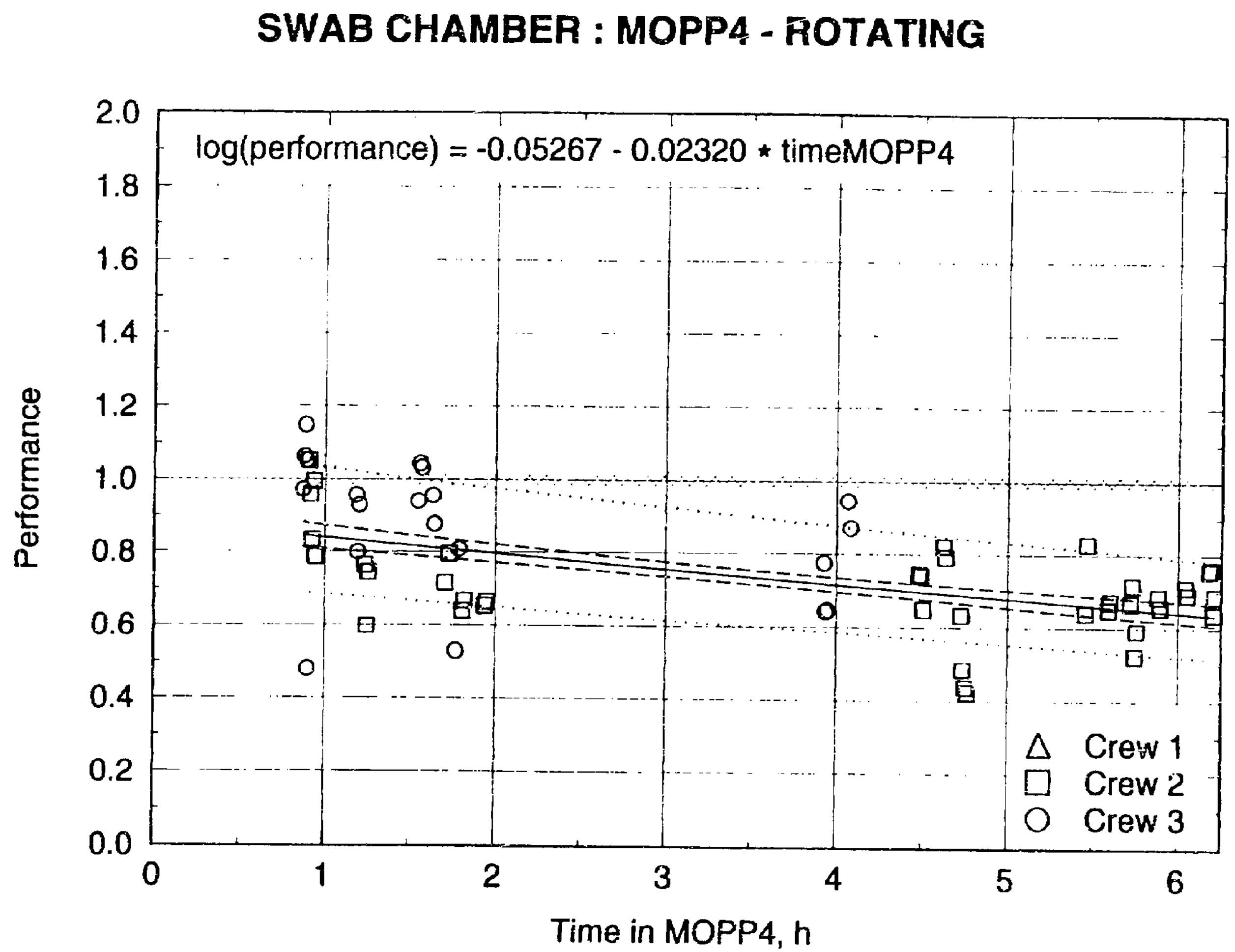


Figure 6-37. Performance vs time-in-MOPP4 with rotating crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **swab chamber.**

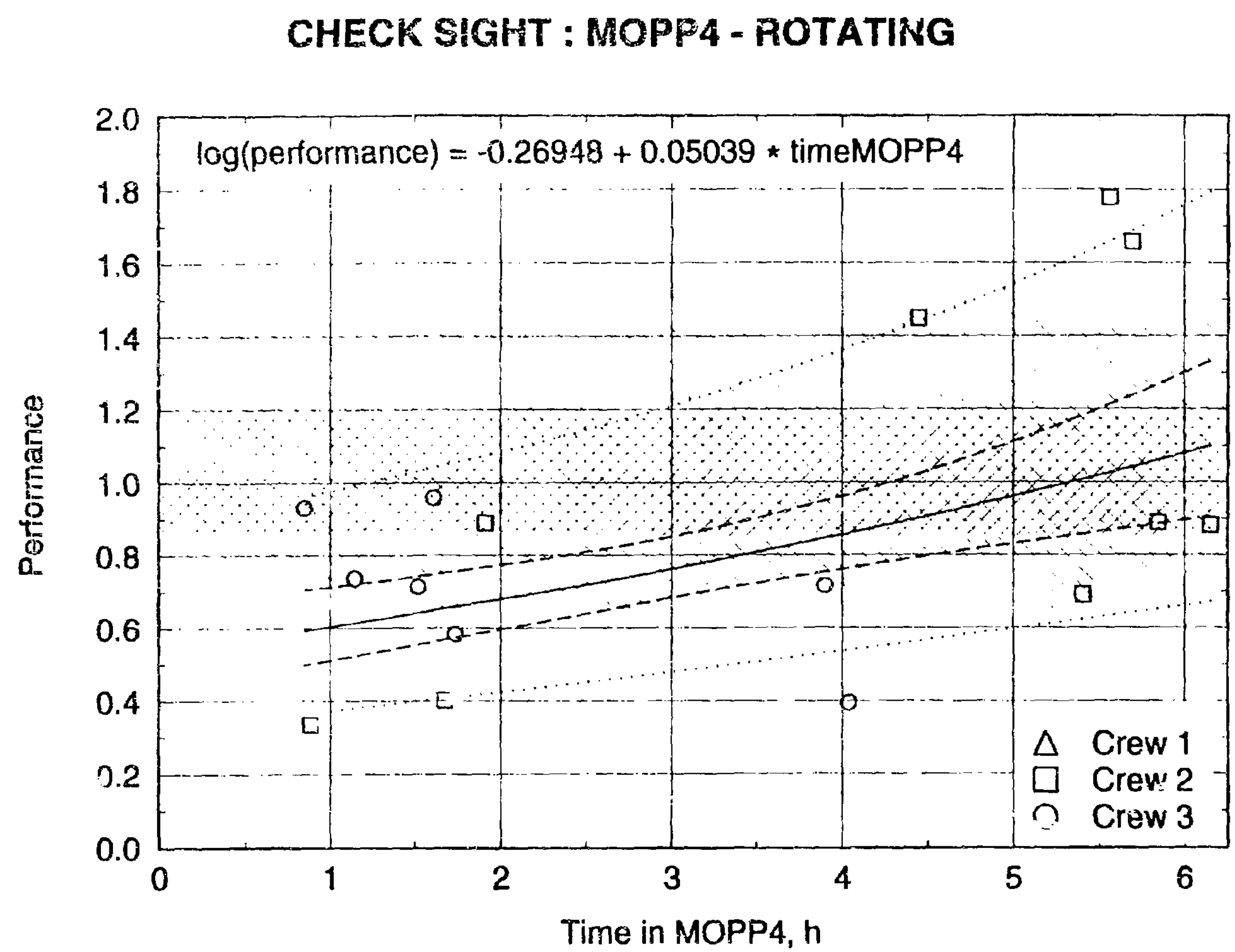


Figure 6-38. Performance vs time-in-MOPP4 with rotating crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **check sight.**

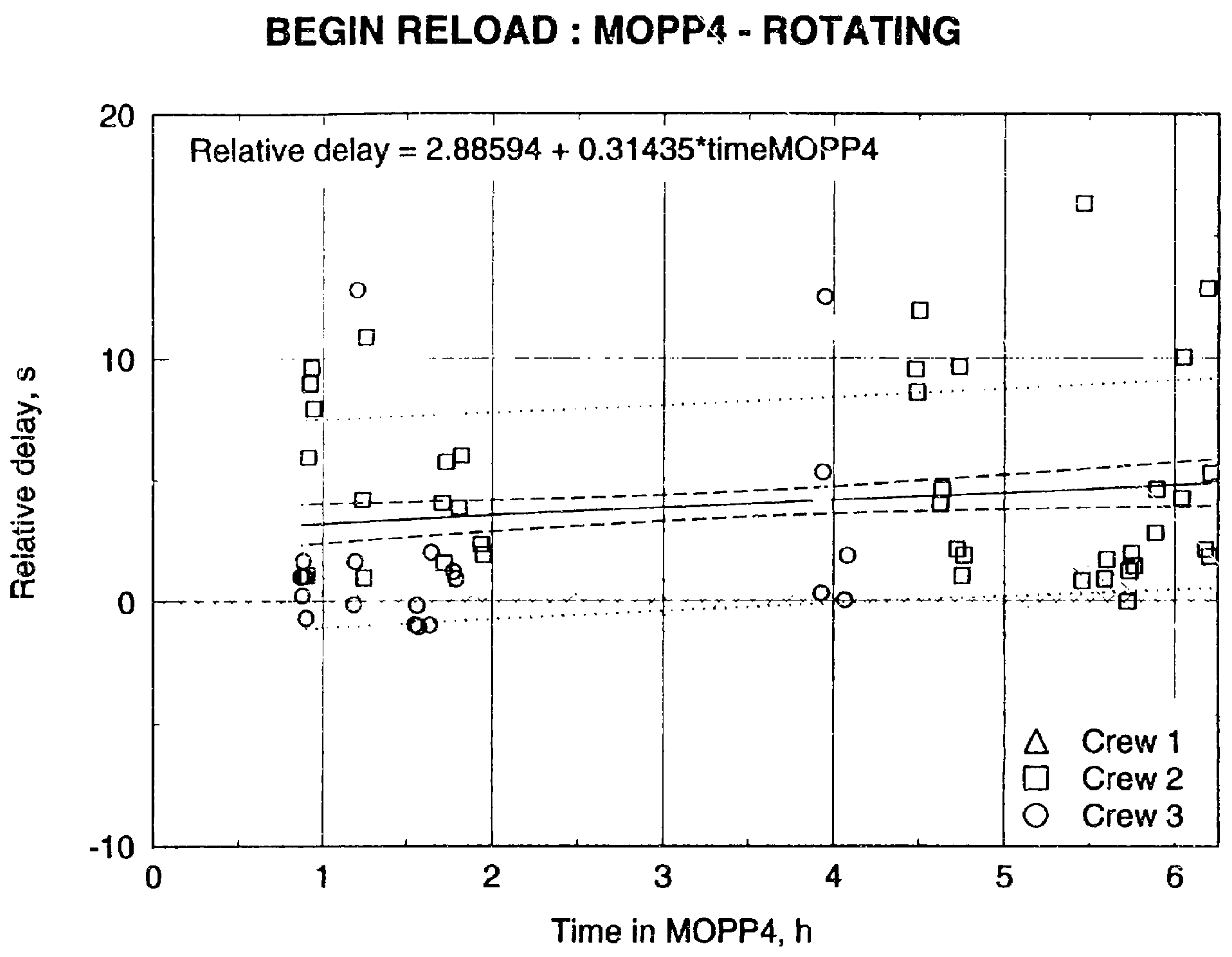


Figure 6-39. Performance vs time-in-MOPP4 with rotating crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **begin reload.**

RELOAD POWDER : MOPP4 - ROTATING

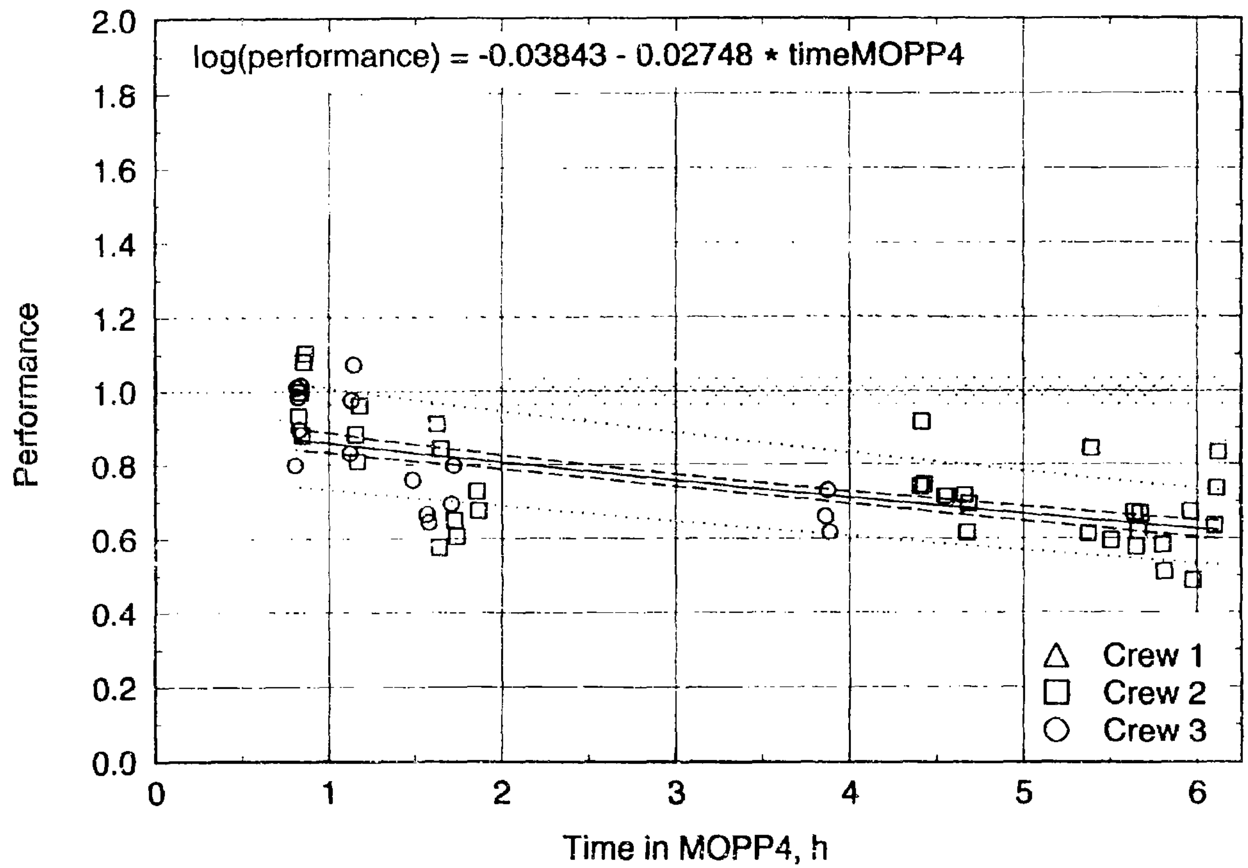


Figure 6-40. Performance vs time-in-MOPP4 with rotating crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **reload powder.**

RELOAD PROJO AND PWDR : MOPP4 - ROTATING

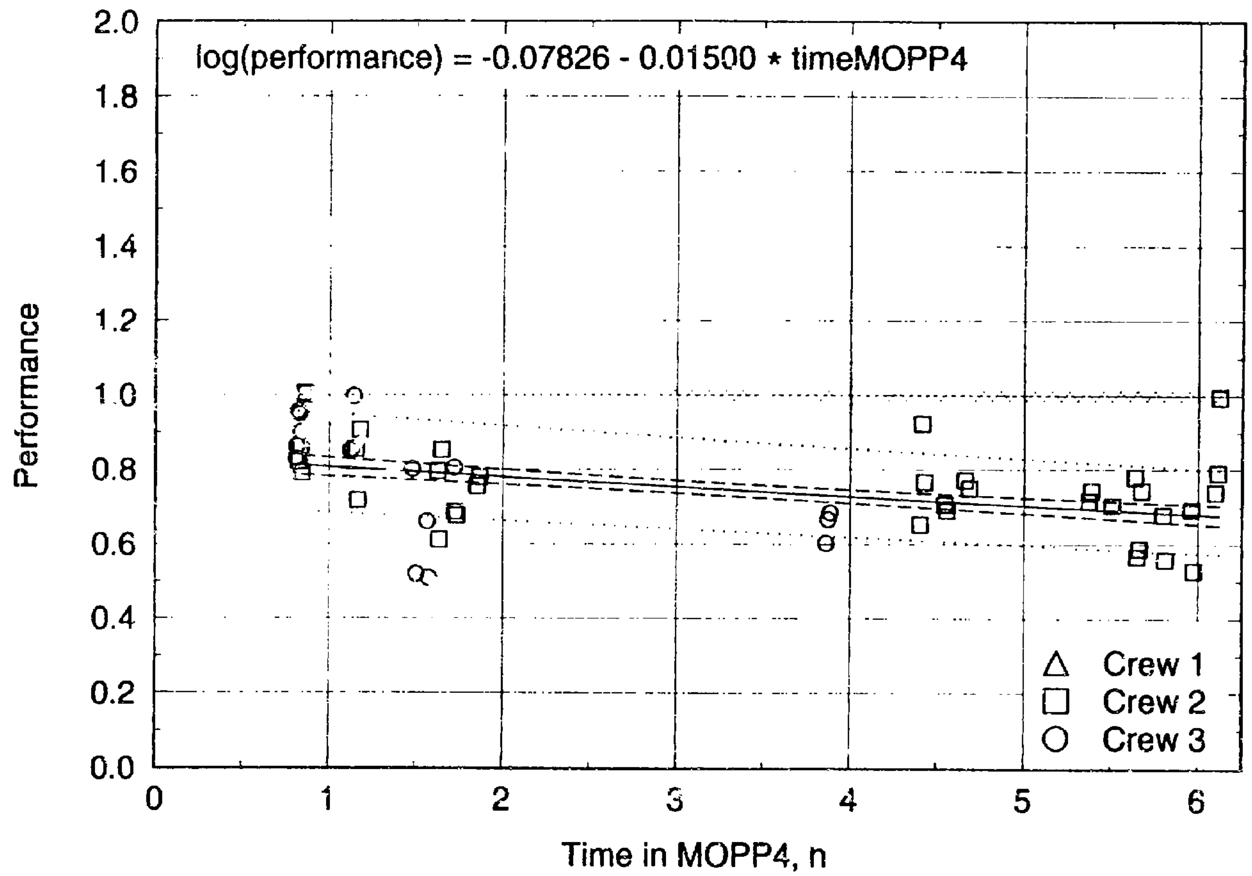


Figure 6-41. Performance vs time-in-MOPP4 with rotating crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **reload projo and pwdr.**

LAST OPEN BREECH : MOPP4 - ROTATING

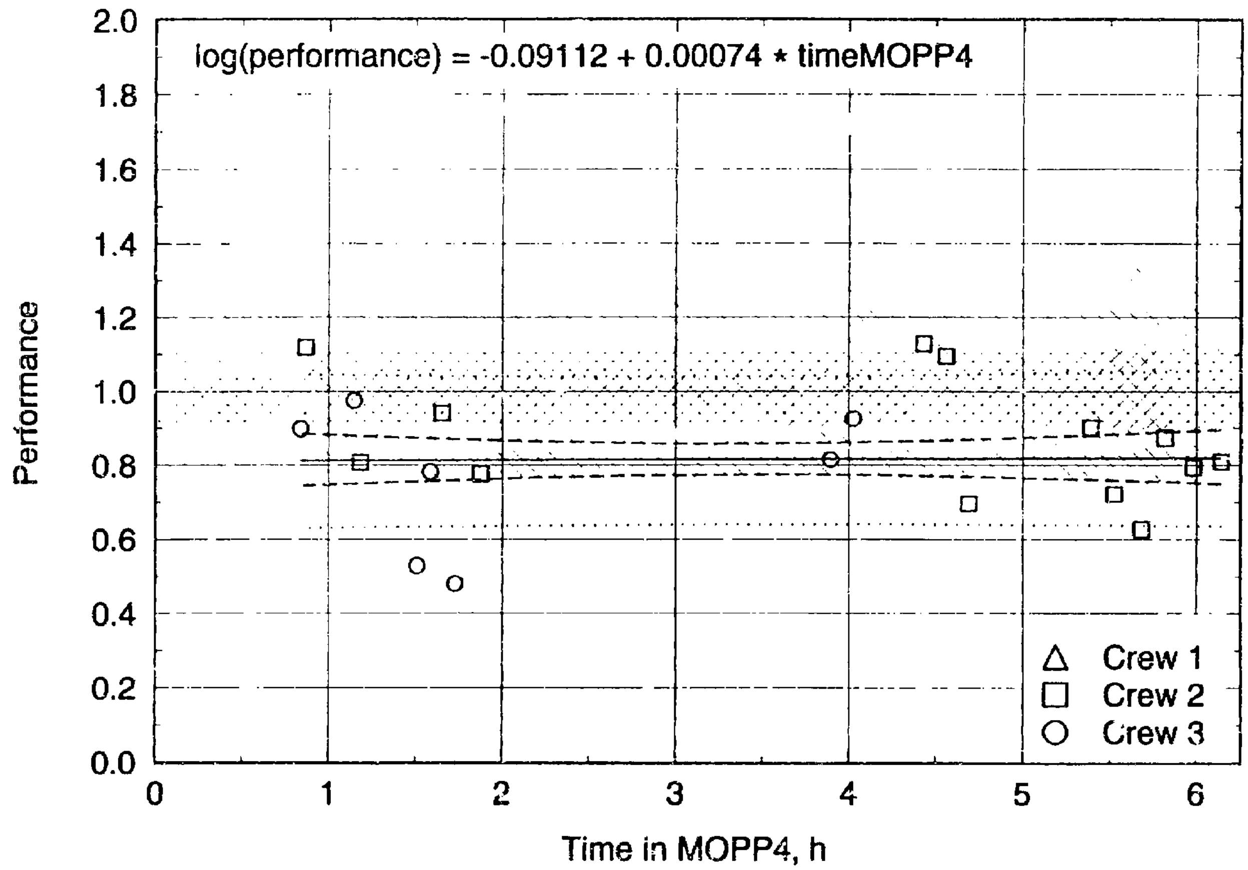


Figure 6-42. Performance vs time-in-MOPP4 with rotating crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **last open breech.**

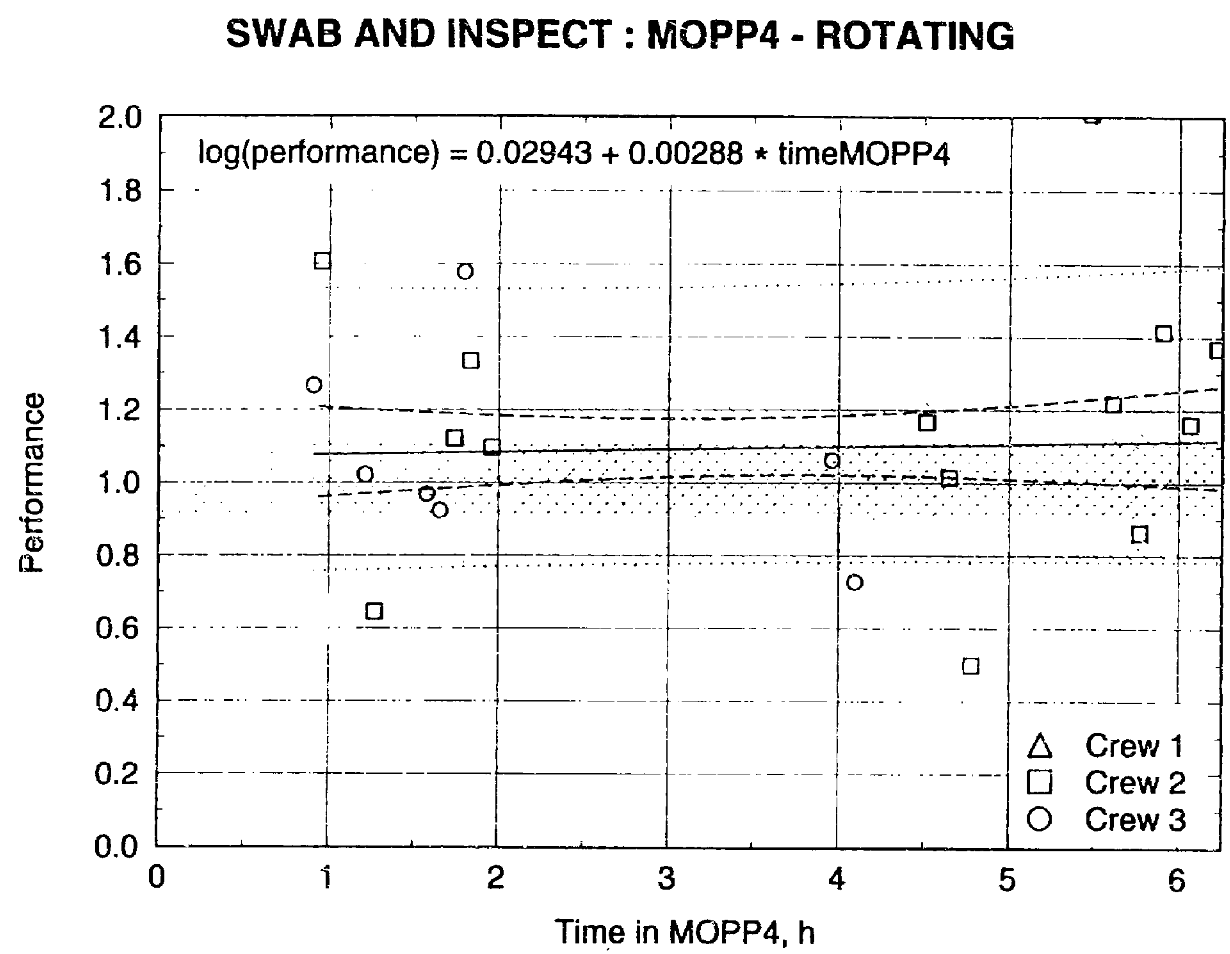


Figure 6-43. Performance vs time-in-MOPP4 with rotating crew positions. The regression line is flanked by the 68% confidence band (dotted) and the standard error of the mean (dashed). The plot includes the standard deviation (striped) and standard error (cross-hatched) of baseline performance. Task: **swab and inspect.**

Table 6-1. Statistical summaries by task for M198 howitzer crew performance vs. time in MOPP4 with standard crew positions.

	relay orders	begin set defl	set defl	traverse tube I	traverse tube II	begin set elev	set elev	elevate tube
Mean of Dependent Variable	-0.16315	3.32142	-0.11754	0.02049	-0.14484	0.19100	-0.06127	-0.02866
Number of Observations	12	9	13	5	9	9	11	10
Total Sum of Squares	0.18412	202.66953	0.54120	0.07665	0.06191	101.09621	0.07189	0.05501
Residual Sum of Squares	0.15268	202.11600	0.46929	0.07660	0.02225	86.06945	0.05127	0.06498
Std. Dev. of Estimate	0.12356	5.37343	0.20655	0.15979	0.05637	3.50651	0.07547	0.09013
R-squared	0.17078	0.00273	0.13286	0.00070	0.64068	0.14864	0.28685	0.00038
Adjusted R-squared	0.08785	-0.13974	0.05403	-0.33240	0.58935	0.02702	0.20761	-0.12457
Degrees of Freedom (df)	10	7	11	3	7	7	9	8
Number of Ind Vars (K)	2	2	2	2	2	2	2	2
F(K-1, df)	2.05946	0.01917	1.68542	0.00210	12.48110	1.22212	3.62011	0.00306
Prob. Value of F	0.18179	0.89378	0.22077	0.96632	0.00956	0.30549	0.08951	0.95724
Constant	-0.07009	2.53442	-0.26032	0.00366	-0.35222	4.52767	-0.20742	-0.03342
Standard error	0.07401	5.95956	0.12401	0.37395	0.06163	4.09326	0.08011	0.09064
Slope	-0.04930	0.49084	0.07437	0.00979	0.12709	-2.51028	0.08646	0.00298
Standard error	0.03435	3.54507	0.05729	0.21365	0.03597	2.27073	0.04544	0.05387
t-ratio	-1.43508	0.13846	1.29824	0.04584	3.53286	-1.10550	1.90266	0.05533
prob t	0.18179	0.89378	0.22077	0.96632	0.00956	0.30549	0.08951	0.95724
Correlation Coefficient	-0.41325	0.05226	0.36450	0.02646	0.80042	-0.38554	0.53559	0.01956
ANOVA Prob. Value of F	0.00027	0.31253	0.00896	-----	0.02142	0.13426	0.77145	0.74514

Table 6-1. Statistical summaries by task for M198 howitzer crew performance vs. time in MOPP4 with standard crew positions.(Continued)

	begin 1st load	load projo	load 1st pwdr	load 1st pro/pwdr	lock breech	fire	open breech	swab chamber
Mean of Dependent Variable	-0.21461	-0.13003	-0.03571	-0.05621	-0.19243	-0.13686	-0.05520	-0.13316
Number of Observations	15	40	9	13	50	59	46	46
Total Sum of Squares	0.32234	0.61833	0.02448	0.11818	0.66574	1.28942	0.37497	0.29810
Residual Sum of Squares	0.31502	0.35804	0.01751	0.10855	0.58359	1.26662	0.32827	0.21033
Std. Dev. of Estimate	0.15567	0.09707	0.05001	0.09934	0.11026	0.14871	0.08638	0.06914
R-squared	0.02270	0.42095	0.28492	0.08151	0.12340	0.02234	0.12454	0.29444
Adjusted R-squared	-0.05247	0.40571	0.18277	-0.00199	0.10514	0.00519	0.10464	0.27841
Degrees of Freedom (df)	13	38	7	11	48	57	44	44
Number of Ind Vars (K)	2	2	2	2	2	2	2	2
F(K-1, df)	0.30199	27.62498	2.78916	0.97618	6.75730	1.30240	6.25931	18.36192
Prob. Value of F	0.59195	0.00001	0.13883	0.34438	0.01237	0.25855	0.01615	0.00010
Constant	-0.17045	0.00418	0.01705	-0.00552	-0.03303	-0.09500	0.00463	-0.05103
Standard error	0.08985	0.02979	0.03572	0.05823	0.06327	0.04148	0.02710	0.02171
Slope	-0.02[illegible]55	-0.07060	-0.02515	-0.02705	-0.10648	-0.02280	-0.03332	-0.04567
Standard error	0.04285	0.01343	0.01506	0.02738	0.04096	0.01998	0.01332	0.01066
t-ratio	-0.54954	-5.25595	-1.67008	-0.98802	-2.59948	-1.14123	-2.50186	-4.28508
prob t	0.59195	0.00001	0.13883	0.34438	0.01237	0.25855	0.01615	0.00010
Correlation Coefficient	-0.15067	-0.64881	-0.533[illegible]3	-0.28550	-0.3512[illegible]	-0.14946	-0.35290	-0.54262
ANOVA Prob. Value of F	0.01[illegible]2	0.00016	0.04192	0.25727	0.00001	0.03302	0.00010	0.01690

Table 6-1. Statistical summaries by task for M198 howitzer crew performance vs. time in MOPP4 with standard crew positions.(Continued)

	check sight	begin reload	reload powder	reload proj/pwdr	last open breech	swab and inspect
Mean of Dependent Variable	-0.26172	3.91021	-0.15117	-0.12083	-0.05342	-0.00306
Number of Observations	13	44	22	38	15	15
Total Sum of Squares	1.06922	779.55652	0.20795	0.21355	0.17375	0.22582
Residual Sum of Squares	0.82632	773.99469	0.10735	0.11689	0.12176	0.22099
Std. Dev. of Estimate	0.27408	4.29284	0.07326	0.05698	0.09678	0.13038
R-squared	0.22718	0.00713	0.48378	0.45263	0.29922	0.02140
Adjusted R-squared	0.15692	-0.01651	0.45796	0.43743	0.24531	-0.05388
Degrees of Freedom (df)	11	42	20	36	13	13
Number of Ind Vars (K)	2	2	2	2	2	2
F(K-1, df)	3.23356	0.30181	18.74289	29.76909	5.55068	0.28430
Prob. Value of F	0.09961	0.58566	0.00033	0.00000	0.03484	0.60290
Constant	-0.51353	3.24533	-0.05824	-0.03757	0.06132	0.03415
Standard error	0.15934	1.37242	0.02655	0.01784	0.05474	0.07748
Slope	0.13597	0.36632	-0.05009	-0.04770	-0.06188	-0.01911
Standard error	0.07561	0.66680	0.01157	0.00874	0.02626	0.03584
t-ratio	1.79821	0.54937	-4.32931	-5.45611	-2.35599	-0.53319
prob t	0.09961	0.58566	0.00033	0.00000	0.03484	0.60290
Correlation Coefficient	0.47663	0.08447	-0.69554	-0.67278	-0.54701	-0.14629
ANOVA Prob. Value of F	0.00026	0.08233	0.00000	0.00000	0.06199	0.00005

Table 6-2. Statistical summaries by task for M198 howitzer crew performance vs. time in MOPP4 with regimented rotation of crew positions.

	relay orders	begin set defl	set defl	traverse tube I	traverse tube II	begin set elev	set elev	elevate tube
Mean of Dependent Variable	-0.15215	-0.78990	-0.01199		-0.15588	1.81577	-0.13103	-0.00635
Number of Observations	21	13	16		12	15	11	16
Total Sum of Squares	0.47305	285.64816	0.47589		0.14520	464.24796	0.21394	0.27012
Residual Sum of Squares	0.46304	284.44922	0.47267		0.13445	292.28662	0.16869	0.16499
Std. Dev. of Estimate	0.15611	5.08518	0.18374		0.11595	4.74169	0.13690	0.10856
R-squared	0.02116	0.00420	0.00678		0.07400	0.37041	0.21155	0.38919
Adjusted R-squared	-0.03035	-0.08633	-0.06417		-0.01860	0.32198	0.12394	0.34556
Degrees of Freedom (df)	19	11	14		10	13	9	14
Number of Ind Vars (K)	2	2	2		2	2	2	2
F(K-1, df)	0.41082	0.04637	0.09551		0.79912	7.64830	2.41474	8.92044
Prob. Value of F	0.52921	0.83345	0.76184		0.39236	0.01605	0.15462	0.00981
Constant	-0.11431	-1.28098	-0.03445		-0.11246	-3.22885	-0.01342	0.14033
Standard error	0.06816	2.68150	0.08596		0.05898	2.19686	0.08621	0.05611
Slope	-0.01125	0.16078	0.00747		-0.01775	1.95045	-0.04636	-0.04560
Standard error	0.01755	0.74669	0.02416		0.01985	0.70526	0.02983	0.01527
t-ratio	-0.64095	0.21533	0.30904		-0.89393	2.76556	-1.55394	-2.98671
prob t	0.52921	0.83345	0.76184		0.39236	0.01605	0.15462	0.00981
Correlation Coefficient	-0.14548	0.06479	0.08231		-0.27203	0.60861	-0.45994	-0.62385
ANOVA Prob. Value of F	0.61375	0.00007	0.08608		0.38904	0.15668	0.62890	0.05272

Table 6-2. Statistical summaries by task for M198 howitzer crew performance vs. time in MOPP4 with regimented rotation of crew positions. (Continued)

	begin 1st load	load projo	load 1st pwdr	load 1st pro/pwdr	lock breech	fire	open breech	swab chamber
Mean of Dependent Variable	-0.18987	-0.16035	-0.17315	-0.14925	-0.21704	-0.10849	-0.08953	-0.12903
Number of Observations	20	80	21	20	80	78	57	59
Total Sum of Squares	0.21422	1.54519	1.01320	0.50158	1.34165	1.13441	0.50584	0.56143
Residual Sum of Squares	0.19800	1.5[illegible]387	0.63178	0.40294	1.23128	1.13377	0.49904	0.43221
Std. Dev. of Estimate	0.10488	0.14046	0.18235	0.14962	0.12564	0.12214	0.09526	0.08708
R-squared	0.07573	0.00409	0.37645	0.19665	0.08227	0.00057	0.01343	0.23017
Adjusted R-squared	0.02438	-0.00868	0.34363	0.15202	0.07050	-0.01258	-0.00451	0.21666
Degrees of Freedom (df)	18	78	19	18	78	76	55	57
Number of Ind Vars (K)	2	2	2	2	2	2	2	2
F(K-1, df)	1.47486	0.32005	11.47066	4.40622	6.99188	0.04317	0.74861	17.04206
Prob. Value of F	0.24027	0.57320	0.00310	0.05018	0.00990	0.83596	0.39068	0.00012
Constant	-0.13840	-0.17498	0.06137	-0.02943	-0.15549	-0.11314	-0.07159	-0.05267
Standard error	0.04843	0.03025	0.07986	0.06616	0.02719	0.02631	0.02427	0.02169
Slope	-0.01481	0.00450	-0.06944	-0.03685	-0.01857	0.00144	-0.00537	-0.02320
Standard error	0.01219	0.00796	0.02050	0.01755	0.00702	0.00692	0.00621	0.00562
t-ratio	-1.21444	0.56573	-3.38684	-2.09910	-2.64422	0.20778	-0.86522	-4.12820
prob t	0.24027	0.57320	0.00310	0.05018	0.00990	0.83596	0.39068	0.00012
Correlation Coefficient	-0.27519	0.06393	-0.61355	-0.44345	-0.28682	0.02383	-0.11588	-0.47976
ANOVA Prob. Value of F	0.53814	0.00000	0.08748	0.06804	0.43266	0.13530	0.30438	0.00054

Table 6-2. Statistical summaries by task for M198 howitzer crew performance vs. time in MOPP4 with regimented rotation of crew positions. (Continued)

	check sight	begin reload	reload powder	reload proj/pwdr	last open breech	swab and inspect
Mean of Dependent Variable	-0.10454	3.91222	-0.12354	-0.12419	-0.08860	0.03931
Number of Observations	16	60	53	52	20	21
Total Sum of Squares	0.65793	1042.04161	0.39793	0.29071	0.18218	0.38178
Residual Sum of Squares	0.50146	018.0805	0.23334	0.24210	0.18214	0.38112
Std. Dev. of Estimate	0.18926	4.18964	0.06764	0.06958	0.10059	0.14163
R-squared	0.23782	0.02299	0.41363	0.16723	0.00023	0.00173
Adjusted-R-squared	0.18338	-0.00615	0.40213	0.15057	-0.05531	-0.05081
Degrees of Freedom (df)	14	58	51	50	18	19
Number of Ind Vars (K)	2	2	2	2	2	2
F(K-1, df)	4.36846	1.36506	35.97544	10.04024	0.00410	0.03288
Prob. Value of F	0.05534	0.24744	0.00000	0.00261	0.94963	0.85803
Constant	-0.26948	2.88594	-0.03843	-0.07826	-0.09112	0.02943
Standard error	0.09201	1.03156	0.01696	0.01741	0.04539	0.06262
Slope	0.05039	0.31435	-0.02748	-0.01500	0.00074	0.00288
Standard error	0.02411	0.26906	0.00458	0.00474	0.01151	0.01589
t-ratio	2.09009	1.16836	-5.99795	-3.16863	0.06406	0.18133
prob t	0.05534	0.24744	0.00000	0.00261	0.94963	0.85803
Correlation Coefficient	0.48767	0.15164	-0.64314	-0.40893	0.01510	0.04156
ANOVA Prob. Value of F	0.37691	0.00852	0.08488	0.68359	0.21817	0.67794

SECTION 7
DISCUSSION

Analysis of performance in this volume focuses on tasks carried out by individuals or by subgroups of the M198 howitzer crew during a fire mission. Table 7-1 presents a characterization of each task according to the number of crewmembers involved, the potential for delay in task completion caused by delay in some other task, and the level of human ability demand of the task. Section 4 presents detailed descriptions of the tasks.

The majority of the M198 tasks require only one crewmember. Except for **relay orders** and **fire**, the tasks involving more than one crewmember are part of loading the howitzer. The *potential for task interruption* is listed as yes (Y) in Table 7-1 if the crewmember(s) involved are sometimes delayed in task completion by waiting for completion of some other task. The tasks requiring only one crewmember and not generally subject to task interruption (N) provide the most straightforward interpretation regarding the effects of MOPP4 on individual task performance.

The degree of degradation of task performance caused by MOPP4 and the associated heat stress depends on the nature and difficulty of the task. To facilitate examination of this effect, Table 7-1 includes ratings of demand on human ability by each task according to a simple taxonomy (Roth, 1992). Tasks have been rated (Roth, 1992) on a seven-point scale for each of the five human abilities or taxons. For example, howitzer loading tasks generally rank highest in physical demand and Gunner and Assistant Gunner tasks rank highest in attention and psychomotor demand. Following a summary of performance degradation results, this ability demand information is used to compare tasks grouped according to performance degradation results.

7.1. SUMMARY OF PERFORMANCE DEGRADATION RESULTS.

Table 7-2 summarizes two major aspects of measured task performance in MOPP4 for the M198 howitzer crews. First, whether performance is degraded for early times in MOPP4 and, second, whether performance degrades significantly with increased time in MOPP4. Answers to both of these questions must be viewed with caution, keeping in mind the limitations of the experimental procedures and the personnel safety considerations. Interpretation and caveats are discussed in the following subsections.

Table 7-1. Characterization of Tasks for an M198 Fire Mission.

Task (or delay (D))	# of crew involved	Potential for task interruption?	Rated Demand on Five Human Abilities[a]				
			Attention	Perception	Psychomotor	Physical	Cognitive
Relay orders	6	N	4	2.5	1	1	4
Begin set deflection (D)	1	Y	-	-	-	-	-
Set deflection	1	N	5	3	4	2.5	4.3
Traverse tube I	1	N	5	3	4	2.5	4.3
Traverse tube II	1	Y					
Begin set elevation (D)	1	Y	-	-	-	-	-
Set elevation	1	N	5	3	4	2.5	4.3
Elevate tube	1	N	5	3	4	2.5	4.3
Begin first load	3	Y	-	-	-	-	
Load projectile	3	N	4.3	2.5	3.3	6	2.3
Load first powder	1	Y	-	-	-	-	-
Load first projo and pwdr	4	Y	4.3	2.5	3.3	6	2.3
Lock breech and prime	1	N	4.3	3	3.3	1.8	3.3
Fire	2	N	-	-	-	-	-
Open breech	1	N	3.3	4	2.8	3.3	2.8
Swab chamber	1	N					
Check sight	1	N	5	3	4	2.5	4.3
Begin reload (D)	3	N	-	-	-	-	-
Reload powder	1	Y	-	-	-	-	-
Reload projo and pwdr	4	Y	4.3	2.5	3.3	6	2.3
Last open breech	1	N	3.3	4	2.8	3.3	2.8
Swab and inspect	1	N					

[a]On a scale of demand increasing from 1 to 7 (Roth, 1992).

Table 7-2. Early degradation and change with time for M198 howitzer task performance.

Task	*MOPP4-S* *Degraded at 1 h?*	*MOPP4-S* *Sign of slope*[a]		*MOPP4-R* *Degraded at 1 h?*	*MOPP4-R* *Sign of slope*[a]
Relay orders	Y	o		Y	o
Begin set deflection	N	o		N	o
Set deflection	N	o		N	o
Traverse tube I	N	o			
Traverse tube II	Y	+	≠[b]	Y	o
Begin set elevation	N	o	≠	N	-[c]
Set elevation	N	o		N	o
Elevate tube	N	o	≠	N[d]	-
Begin first load	Y	o		Y	o
Load projectile	Y	-	≠	Y	o
Load first powder	N	o	≠	N	-
Load first projo and pwdr	N	o		N	o
Lock breech and prime	Y	-		Y	-
Fire	Y	o		Y	o
Open breech	N	-	≠	Y	o
Swab chamber	Y	-		Y	-
Check sight	Y	o	≠	N	o
Begin reload	Y	o		Y	o
Reload powder	Y	-		Y	-
Reload projo and pwdr	Y	-		Y	-
Last open breech	N	-	≠	N	o
Swab and inspect	N	o		N	o

[a]Sign of slope of performance versus time in MOPP4 is "o" if *prob t* from regression analysis is ≥0.05, that is, no statistically significant slope. Blank entry means no data available.

[b]The ≠ symbol highlights a difference between MOPP4-S and MOPP4-R.

[c]The regression slope is actually positive for this delay time, but corresponds to worsening performance.

[d]The performance at 1 h is above 1.0 for this task, but the statistical significance is marginal.

7.1.1. Early Degradation -- the Encumbrance Effect.

Encumbrance effects are the principle cause of performance degradation when environmental conditions are cool enough that heat stress is negligible. Even in a warmer environment, Section 5 shows that it takes time for heat strain as measured by body core temperature to reach performance-degrading levels after protective clothing is donned. Therefore, for a period of time after donning MOPP4, only encumbrance affects performance.

If time in MOPP4 were a valid measure of heat strain in this exercise, then the regression analyses presented in Section 6 would separate the performance degradation due to heat strain from that due to encumbrance effects. Specifically, the extrapolated value of the regression lines at zero time in MOPP4 would be the expected degradation from encumbrance effects.

Unfortunately, the discussion of heat stress and heat strain in Section 5 shows that two factors argue against this extrapolation. First, the ambient temperature and humidity were not constant, so that heat stress was not a linear function of time in MOPP4. Second, the metabolic work rate of the crewmembers was not constant. For example, the crews conducted emplacement activities immediately after donning MOPP4 and then paused to answer a questionnaire before beginning fire missions. In addition, fire missions were interrupted by the road march for resupply and by occasional administration of questionnaires by test personnel.

The practical approach adopted for the purposes of Table 7-2 and this discussion is to examine the "early" performance degradation at 1 h in MOPP4 derived from the regression lines presented in Section 6. Figures 6-1 and 6-23 show that the average time in MOPP4 at the beginning of the first fire mission in the five MOPP4 scenarios was about 1 h. The performance degradation at this time may not be a pure encumbrance effect; however, because ambient temperatures were lower in the morning and because heat strain takes some time to build up, the cumulative heat strain at 1 h is significantly less than for the later fire missions. Therefore, to avoid the uncertainty of extrapolating to zero time in MOPP4, the early performance degradation at 1 h in MOPP4 is used as the indicator of the level of performance degradation from the encumbrance of MOPP4.

The deviation from baseline of the early performance in MOPP4 at 1 h is considered significant if a t-test of the null hypothesis (that is, no deviation) gives a probability of less than 0.05 of obtaining the observed deviation at random in the absence of a true difference between MOPP4 and baseline performance. For each task in the MOPP4-S and MOPP4-R scenarios,

Table 7-2 answers the question *Degraded at 1 h?* with a yes or no (Y or N) according to this criteria.

Table 7-2 may be checked visually by examining Figures 6-1 through 6-43 at 1 h in MOPP4. Each figure includes a regression line for performance in MOPP4 with dashed lines representing the standard error and a cross-hatched band centered at 1.0 representing the standard error of baseline performance. Since the baseline and MOPP4 performances have similar standard errors, the *t*-test will show a significant deviation whenever the separation between MOPP4 performance and baseline exceeds about 3 standard errors.

The results in Table 7-2 for encumbrance are about equally divided, with 22 cases showing a significant degradation at 1 h in MOPP4 and 21 cases showing no significant degradation. Of course, a null result (N) does not prove that there is no performance degradation, only that the degradation is smaller than can be observed with this data. In summary, 12 of the 22 tasks listed in Table 7-2 show a significant early performance degradation in at least one of the two MOPP4 scenarios.

7.1.2. Dependence of Degradation on Time in MOPP4.

The regression analyses of performance versus time in MOPP4 as presented in Section 6 test for significant change in performance during the 2 to 5 hour period of the fire missions. As discussed in Section 5, the analysis of performance variations with respect to measures of heat stress or heat strain other than time in MOPP4 is beyond the scope of this report. For each task, Table 7-2 shows whether a significant change in performance is observed during fire missions for each task by listing the sign of the slope of the regression line of log(performance) versus time in MOPP4. Statistical data for the slopes are summarized in Tables 6-1 and 6-2. If the *prob t* value for a task is greater than or equal to 0.05, the measured slope is statistically consistent with zero and "o" is entered in the *sign of slope* column in Table 7-2. If the *prob t* value is less than 0.05, the slope is statistically significant and a + or - is entered in Table 7-2 according to the sign of the slope.

Of the 43 measured slopes, 28 are consistent with zero, that is, no measured variation of performance over the fire missions. Of the remainder, 14 show a significant worsening of performance with time in MOPP4 and only one task shows improvement in performance. The improving performance for **traverse tube II** occurs for MOPP4-S and not MOPP4-R. It is probably an artifact of the task definition, which included a wait time for completion of **elevate tube**. This task interaction may change as time progresses leading to an apparent improvement in performance. Of course, a null result (o) does not prove the absence of a change in performance degradation, only that the change is too small to be observed with this data. In

summary, 10 of the 22 tasks listed in Table 7-2 show a significant performance degradation with time in MOPP4 in at least one of the two MOPP4 scenarios.

7.1.3. Caveats.

The primary caveats regarding the measured variation of performance with time involve the removal of crewmembers from the exercise for medical safety. As discussed in Section 6, this removal means that the measured performance values are conditional; they represent the performance of crewmembers who have not exceeded the heat strain limits imposed for individual safety. Second, as crewmembers were removed, there were changes in crewmember assignments. This shifting of crew positions has counteracting effects. Performance may be maintained for a given task by bringing in a crewmember with less heat strain. On the other hand, performance may be worsened if the new crewmember is less experienced with the task. Finally, the average workload per crewmember increases as the size of the crew decreases. The data to examine these effects is available in the record of this exercise but such examination is beyond the scope of this report.

In conclusion, 12 of the 22 tasks analyzed in this effort show a significant performance degradation from the encumbrance of MOPP4 and 10 of 22 tasks show a significant increase in degradation with time in MOPP4.

7.2. TASK GROUPING BY DEGRADATION.

Table 7-3 groups the M198 howitzer tasks in a two-by-two matrix according to the presence or absence of performance degradation at 1 h (representing encumbrance) and the presence or absence of increased degradation over time in MOPP4. Table 7-3 does not include the three delays, **begin set deflection**, **begin set elevation**, and **begin reload**. Also, Table 7-3 omits the **check sight** task since it was poorly defined during data collection. Table 7-3 shows the number of crewmembers involved in each task.

The majority (13 of 22) of the tasks in Table 7-2 show agreement between the results for MOPP4-S and MOPP4-R scenarios. Those that disagree are highlighted in Table 7-2 with an ≠ sign. For these cases, the task placement in Table 7-3 was chosen to best represent a consensus of the measurements.

Tasks with no potential for interruption by another task are flagged in Table 7-3 with an "*" for tasks involving only one crewmember and a "+" tasks involving more than one crewmember. There is a tendency (5 of 9) for tasks involving one crewmember with no potential for interruption to show neither performance degradation at 1 h nor a decrease in performance over time in MOPP4. Conversely, there is an even stronger tendency (5 of 6) for tasks that show no

encumbrance and no slope to be tasks performed by one crewmember with no potential for interruption by other tasks.

Table 7-3. Tasks grouped by presence or absence of early degradation (encumbrance) and slope of performance over time in MOPP4. Task-averaged human ability demands within boxes are derived from Table 7-2; number of crewmembers involved in each task is in parentheses.

	Steady performance over time in MOPP4	*Decreasing performance over time in MOPP4*
Performance at 1 h in MOPP4 consistent with baseline	*** Set deflection (1)** *** Traverse tube I (1)** *** Set elevation (1)** **Load first projo and powder (4)** *** Last open breech (1)** *** Swab and inspect (1)** Att Per Psy Phy Cog 4.3 3.3 3.5 3.4 3.5	**Load first powder (1)** *** Elevate tube (1)**
Performance degraded significantly at 1 h in MOPP4	**+ Relay orders (6)** **Traverse tube II (1)** **Begin first load (3)** **+ Fire (2)** *** Open breech (1)** Att Per Psy Phy Cog 4.1 3.2 2.6 2.3 3.7	**+ Load projectile (3)** *** Lock breech and prime (1)** *** Swab chamber (1)** **Reload powder (1)** **Reload projo and powder (4)** Att Per Psy Phy Cog 4.1 3.0 3.2 4.3 2.7

* Tasks performed by one crewmember with no potential interruption by other tasks.
+ Tasks performed by more than one crewmember with no potential interruption by other tasks.

All three of the tasks with no potential for interruption and involving more than one crewmember had significant degradation at 1 h. In fact, of the six tasks in Table 7-3 that involve more than 1 crewmember, five show significant encumbrance degradation. As another indication, the set of tasks with no encumbrance degradation at 1 h involve an average of 1.4 crewmembers. On the other hand, tasks that are degraded at 1 h involve an average of 2.3 crewmembers. The

implication is that MOPP4 encumbers M198 crewmember interaction, causing early performance degradation for tasks that involve more than one crewmember.

The number of crewmembers required for a task seems to exert less influence on whether or not performance degradation increases with time in MOPP4. The average number of crewmembers is 2.0 and 1.7, respectively, for tasks with steady performance and tasks with decreasing performance.

Next, the four groups of tasks in Table 7-3 are examined for correlations between performance degradation and the human ability demands of the tasks. To this end, the demand on each ability is averaged over the task groups. The upper right quadrant in Table 7-3 is skipped since ability demand ratings are available in Table 7-1 for only one of the two tasks in that quadrant. Inspection of the averages (displayed in Table 7-3) shows that the strongest correlation involves whether or not the performance decreases with time in MOPP4. The tasks that have steady performance over time in MOPP4 have lower physical demand and higher cognitive demand than the tasks for which performance degrades with time in MOPP4. Therefore, decreasing performance over time in MOPP4 is associated with higher physical demand.

To look for a link between the average human ability demands of the task groups and the presence or absence of early performance degradation, it is best to examine the data for tasks involving only one crewmember in order to eliminate the influence of crewmember interactions noted above. The average demands for the single crewmember tasks with no early encumbrance degradation are 4.4, 3.3, 3.6, 2.8, and 3.8 (ordered as in Table 7-3). The averages for the single crewmember tasks showing early encumbrance degradation are 4.0, 3.5, 3.2, 2.7, and 3.3. Comparison of these two sets of average ratings shows that encumbrance degradation in the M198 data for single crewmember tasks is associated with an increase in the rated demand for only one of the five human abilities, perception, and that increase is small. Apparently, the encumbrance of MOPP4 for individuals acts on human skills not well resolved by the five component taxonomy of Roth (1992).

7.3. INFLUENCE OF PRIMER RACK.

From the standpoint of analyzing the effect of MOPP4 on performance, the introduction of a rack to hold primers for the convenience of the No. 1 Cannoneer on certain missions is an extraneous factor. However, the primer rack did not seem to improve performance on the **lock breech and prime** task.

Crews 2 and 3 performed their MOPP4-S scenarios with standard primer procedures (without the primer rack) but performed their MOPP4-R scenarios <u>with</u> the primer rack. Since there were occasional shifts in crew position during the MOPP4 scenarios, it is best to compare the **lock**

breech and prime task times for initial fire missions in each scenario in order to compare times for the same No. 1 Cannoneer with and without the primer rack. For both Crew 2 and Crew 3, the MOPP4-R scenarios were performed after the MOPP4-S scenarios. Therefore, learning should improve the times on the MOPP4-R. If the primer rack improves performance, then both factors would improve the MOPP4-R times relative to MOPP4-S. On the contrary, MOPP4-R times are slower than the MOPP4-S times. The primer rack did not improve the overall task time for the **lock breech and prime** task. Also, the presence of the primer rack does not alter conclusions presented in this Section since Table 7-2 shows consistent results for the **lock breech and prime** task with and without the primer rack.

SECTION 8
CONCLUSION

The data in this report provides a comprehensive statistical characterization of task performance for the M198 howitzer crew in both BDU and MOPP4. Table 7-3 shows which tasks are and which are not subject to encumbrance degradation by the MOPP4 protective gear. In addition, it shows which tasks are most strongly affected by accumulating heat strain.

Fire mission scenarios in MOPP4 were conducted with standard crew positions (MOPP4-S) or with rotating crew positions to distribute the metabolic work load among crewmembers (MOPP4-R). The data for MOPP4-S and MOPP4-R are presented separately to facilitate future comparison of operational effectiveness of the alternate procedures. Such comparison is not trivial since day-to-day variations in meteorology can explain a substantial part of the variation in the number of fire missions completed (determined by crew attrition from heat strain) independently of whether the scenario was MOPP4-S or MOPP4-R (see Section 5). The analysis of relative effectiveness of the MOPP4-S and MOPP4-R procedures would require time-dependent modeling of ambient meteorological conditions and metabolic work rate of the crew.

Considering all MOPP4 data, 12 of 22 M198 tasks show significant encumbrance degradation when judged by performance on the first fire mission of each day. The first fire mission was typically conducted after about 1 h in MOPP4. Performance degradation at this time is an approximate indicator of encumbrance effects since heat strain accumulated early in the day is much less than that during subsequent fire missions. Careful analysis of the time-dependent meteorological conditions and the recorded physiological data would be required to extrapolate measured performance values to zero heat strain, thereby extracting an improved estimate of encumbrance degradation.

Regression analysis of performance versus time in MOPP4 shows that performance degradation increases with time in MOPP4 for 10 of 22 tasks. Tables 6-1 and 6-2 provide statistical parameters that may be used to model task performance versus time in MOPP4 for the ambient conditions of this exercise. Further analysis, using time-dependent meteorological data with physiological models, would permit generalization to other ambient conditions.

Task performance results in MOPP4 are analyzed by placing the M198 tasks in four groups (Section 7) according to whether each task shows encumbrance degradation and whether it shows increasing degradation with time in MOPP4. Examination of the nature of the M198 tasks in each group leads to the following conclusions:

1. M198 tasks performed by a single crewmember with no potential for interruption (delay) by another task are least likely to show performance degradation from MOPP4.

2. M198 tasks that involve more than one crewmember are more likely to show encumbrance degradation than tasks performed by a single crewmember.

3. For M198 tasks, the likelihood of increasing degradation with time in MOPP4 is not sensitive to the number of crewmembers involved.

4. The M198 tasks for which performance degrades with increasing time in MOPP4 tend to have higher physical demand and lower cognitive demand than tasks that have little or no increase in degradation.

The richness of the data gathered and compiled during this effort enables further analyses. Possibilities are:

1. Correlation of task performance with a time-dependent analysis of meteorological conditions and crewmember metabolic work rate.

2. A more detailed analysis of the human ability demands associated with performance degradation from MOPP4 encumbrance and heat strain.

3. Use of the data to support development of methods such as the Task-Taxon-Task (T^3) methodology for generalizing stress-induced performance degradation from one set of tasks to another.

4. Construction and validation of a sequential network model of M198 crew operations.

5. Examination of motivational and leadership factors through correlation of performance with mood questionnaire data collected by other researchers during the exercise.

Finally, the task completion times presented in Appendix C are included in digital form on the 3.5" diskette that accompanies this report.

SECTION 9
REFERENCES

McClellan, G. E., *Task Time Data Collection for the M198 Howitzer*, Pacific-Sierra Research Corporation, Report 2322, November 1992.

McNally, R. E., M. M. Stark, D. E. Lee, and W. J. Ivusich, *P^2NBC^2 Heat Strain Decision Aid Users' Guide (Version 2.0)*, SAIC, Joppa, Maryland, March 1992.

Redmond, COL Daniel, Private communication, Department of Behavioral Biology, U.S. Army Walter Reid Army Institute of Research, Silver Spring, Maryland, August, 1993.

Roth, J. Thomas, *Reliability and Validity Assessment of a Taxonomy for Predicting Relative Stressor Effects on Human Task Performance*, Technical Report 5060-1, Applied Sciences Associates, Inc., Butler, Pennsylvania, July 1992.

Taylor, H. L. and J. Orlansky, 1991, *The Effects of Wearing Protective Chemical Warfare Combat Clothing on Human Performance*, IDA Paper P-2433, Institute for Defense Analysis, Alexandria, VA, August, 1991.

Taylor, H. L. and J. Orlansky, 1993, *The Effects of Wearing Protective Chemical Warfare Combat Clothing on Human Performance, Aviation, Space, and Environmental Medicine*, Vol.64, No. 3, S[illegible]ion II, March, 1993, pp. A1-A41

Zubal, O., Private communication, U.S. Army Human Engineering Laboratory, Aberdeen Proving Ground, September, 1992.

APPENDIX A

EVENT TIMELINES FOR EACH FIRE MISSION

This appendix presents event timelines for the fire missions analyzed in this volume. Table A-1 explains the abbreviations used in the timeline figures in terms of the event definitions of Section 2. Data processing methods used to construct these timelines are described in Section 3.

Table A-1. Explanation of abbreviations used in timeline figures.

Event abbreviation on timelines	*Event name (from Section 2)*
Orders	*Receive/call out fire mission*
Set Defl	*Set deflection*
Traverse	*Traverse tube/level bubble*
Chk Sight	*Check sight picture*
Set Elev	*Set quadrant elevation (QE) on range quadrant*
Elevate	*Elevate tube/level bubbles*
Depress	*Depress tube for loading*
Load	*Load start (set tray)*
Ram	*Ram projectile*
Cls Brch	*Close breech; prime*
Safe Chk	*Safety check*
Standby	*Standby*
Fire	*Fire*
Opn Brch	*Open breech/swab bore*

In the timelines, impulse events are indicated by filled triangles and the durations of continuous events are indicated with horizontal lines. Measured event times correspond to the

lower tips of the triangles and to the vertical hash marks at either end of the lines. When the start or end time of a continuous event is missing from the data file, the available endpoint is plotted with a filled triangle.

Fire missions from 10 August 1994 (the first day of the exercise) are excluded from analysis for reasons discussed in Volume 1 and do not appear in this appendix. Also, high angle fire missions and zone and sweep fire missions, which are analyzed in Volume 1 but not in this volume, are not included here.

In the timeline figures, events are plotted with time in seconds along the horizontal axis. Table A-2 provides data for interpreting these times. The mission scenario began each morning with an order to "move to the firing point" (see Section 1 of this report and McClellan, 1992). Times referenced to this order are called *scenario time*.

In order to be ready to record event times, observers had to start their data logging software prior to the move to firing point. At startup, the software recorded the computer clock time and thereafter recorded event times as time elapsed since startup. This elapsed time, corrected to the clock of Logger No. 1 (as discussed in Section 3), is used for convenience to plot timelines in this appendix. Scenario time for the first 7 fire missions of each day's scenario may be derived from the elapsed time by subtracting the recorded time of the "move to firing point". This time is listed in the third column of Table A-2 as the *morning move time*.

After the first 7 fire missions of each scenario, the crew conducted a road march for resupply. During resupply, observers saved their data files from the first 7 fire missions and restarted the data logging software, thereby establishing a new origin for elapsed time on subsequent fire missions. Event times for the 10 fire missions after resupply (Fire Missions 8 through 17) are plotted in terms of this new elapsed time. Table A-2 gives the time by which the second set of elapsed times is offset relative to the first set for each day. The time is listed in the fourth column as *resupply offset*. Scenario time, (still defined relative to the first "move to firing point") for the fire missions after resupply is obtained from plotted elapsed time by adding the *resupply offset* as well as subtracting the *morning move time*.

For exercises in MOPP4, accumulated *time in MOPP4* is an important variable for specifying heat stress. For the data reported here, there is only a few minutes difference between scenario time and time in MOPP4. The crews went from MOPP2 to MOPP4 at the holding point just before the first "move to firing point" order and remained in MOPP4 during resupply. Table A-2 lists the time taken by each crew to go from MOPP2 to MOPP4 as well as the elapsed time from the order to "go to MOPP4" to the "move to the firing point".

Table A-2. Various reference and offset times (in seconds) for each scenario.

Date (1992)	*Crew*	*Morning move time (s)*	*Resupply offset (s)*	*Time to reach MOPP4 starting from MOPP2 (s)*	*Time between "go to MOPP4" and first "move to firing point" command (s)*
12 Aug	1	610.	--	(not measured)	183.7
14 Aug	1	2170.	8904.	(BDU)	--
17 Aug	2	3232.	11479.	(BDU)	--
19 Aug	2	4334.	--	124.3	549.8
21 Aug	2	3636.	13049.	167.1	297.3
24 Aug	3	3807	15198.	222.5	280.2
26 Aug	3	609.	7772.	(BDU)	--
28 Aug	3	1978.	10912.	183.8	233.7

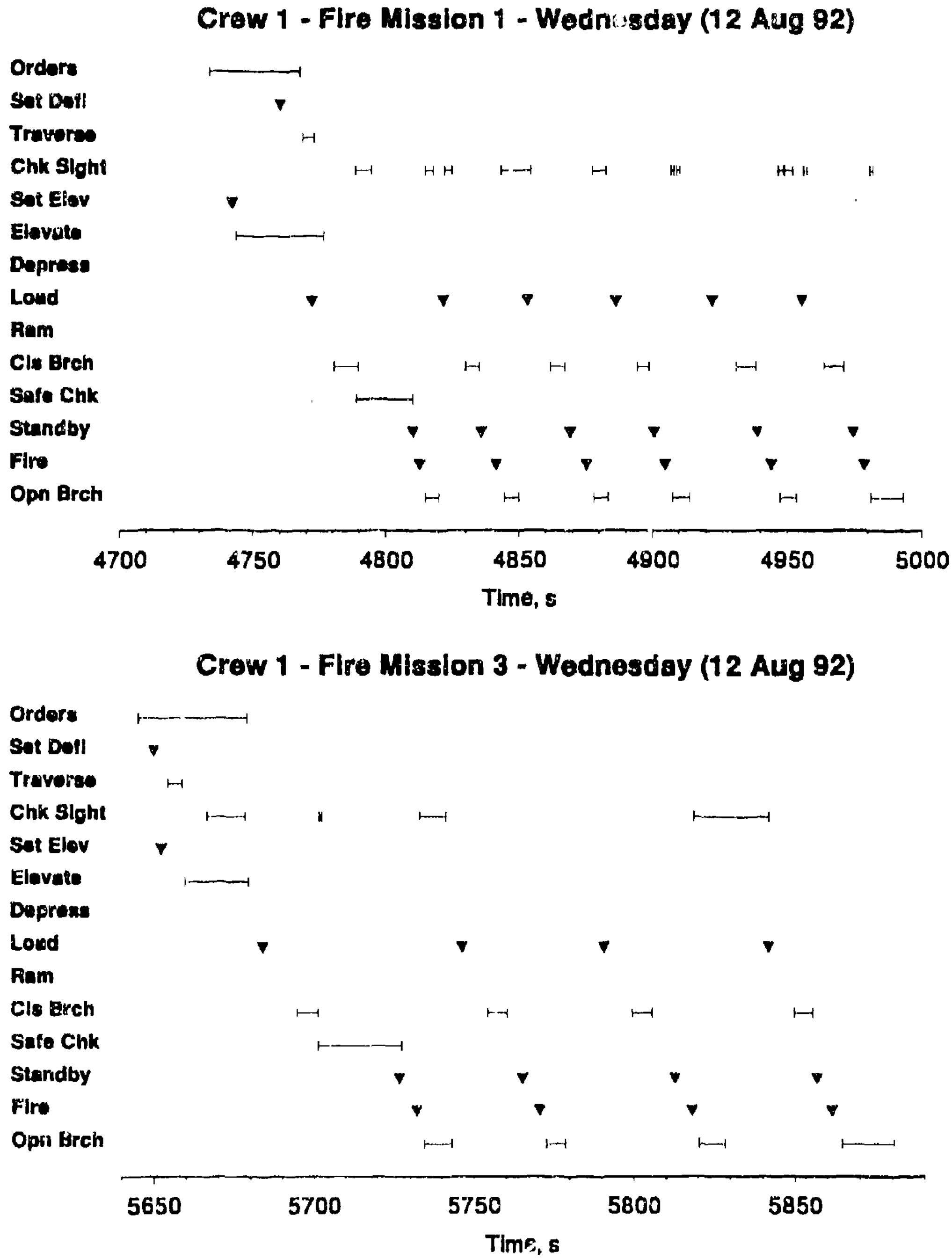
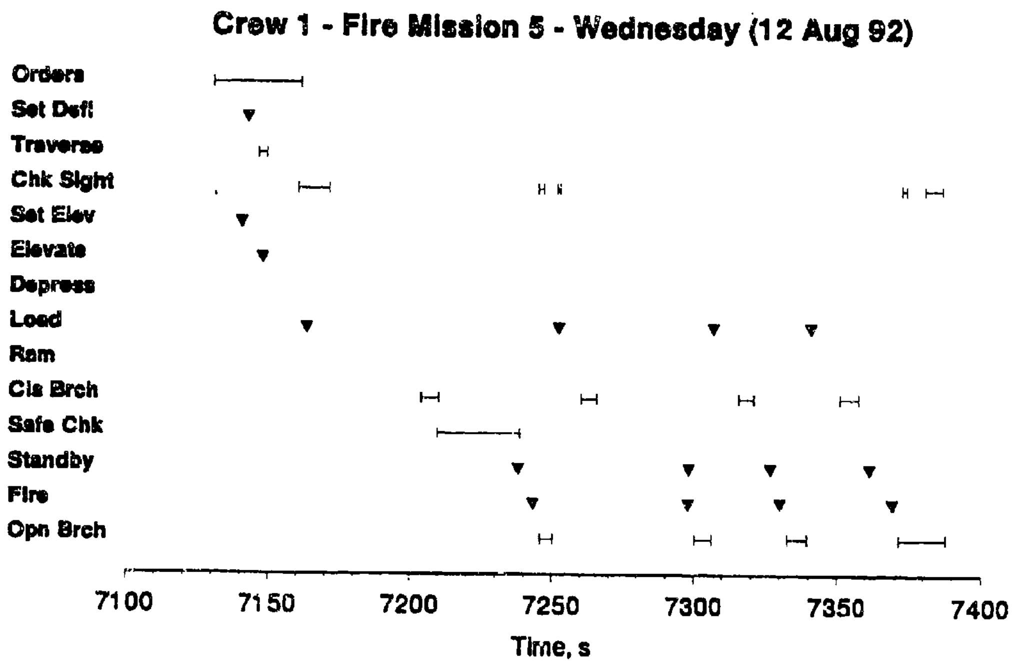


Figure A-1. Crew 1 timelines for fire missions 1 and 3 in MOPP4-S.



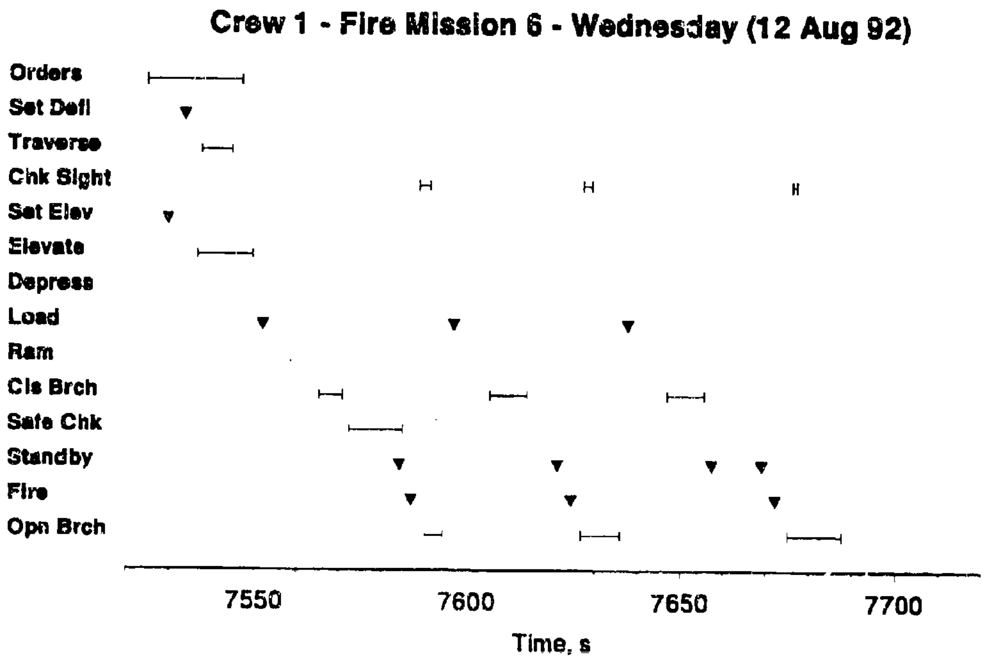


Figure A-2. Crew 1 timelines for fire missions 5 and 6 in MOPP4-S.

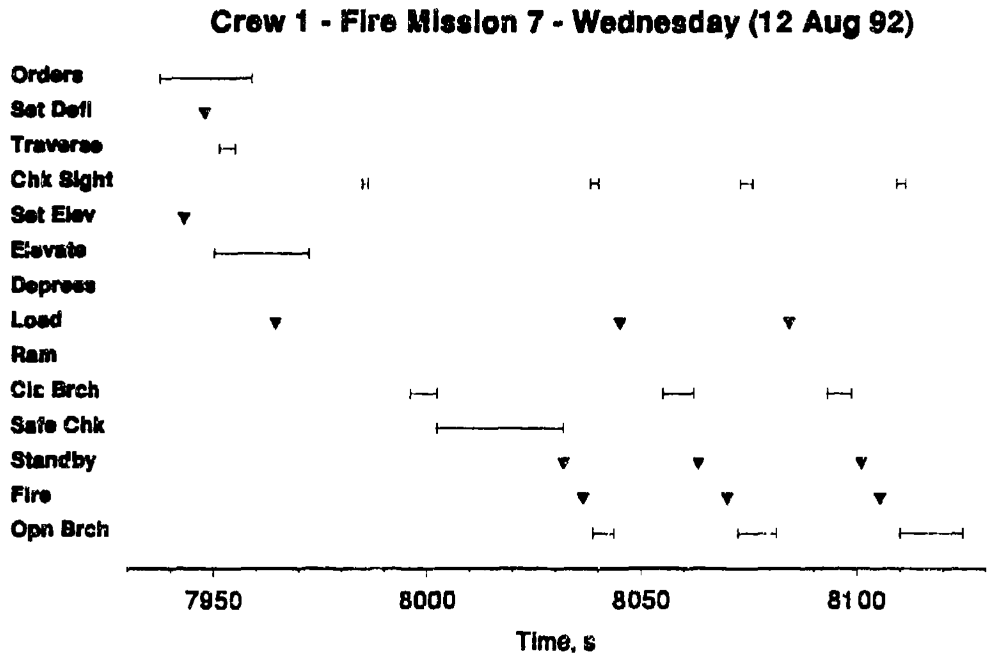
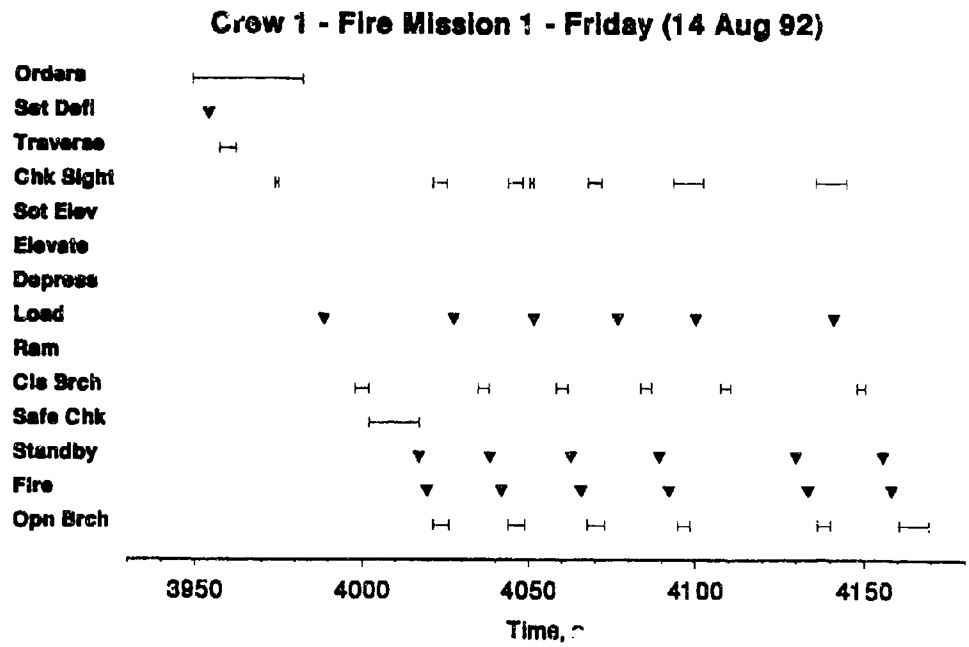


Figure A-3. Crew 1 timelines for firemission 7 in MOPP4-S.



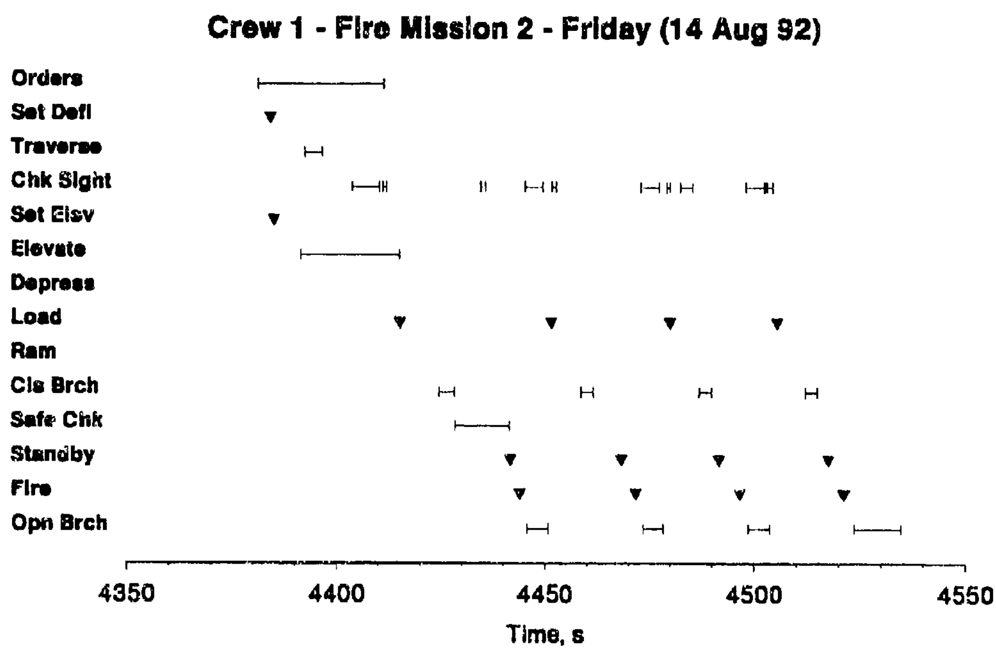
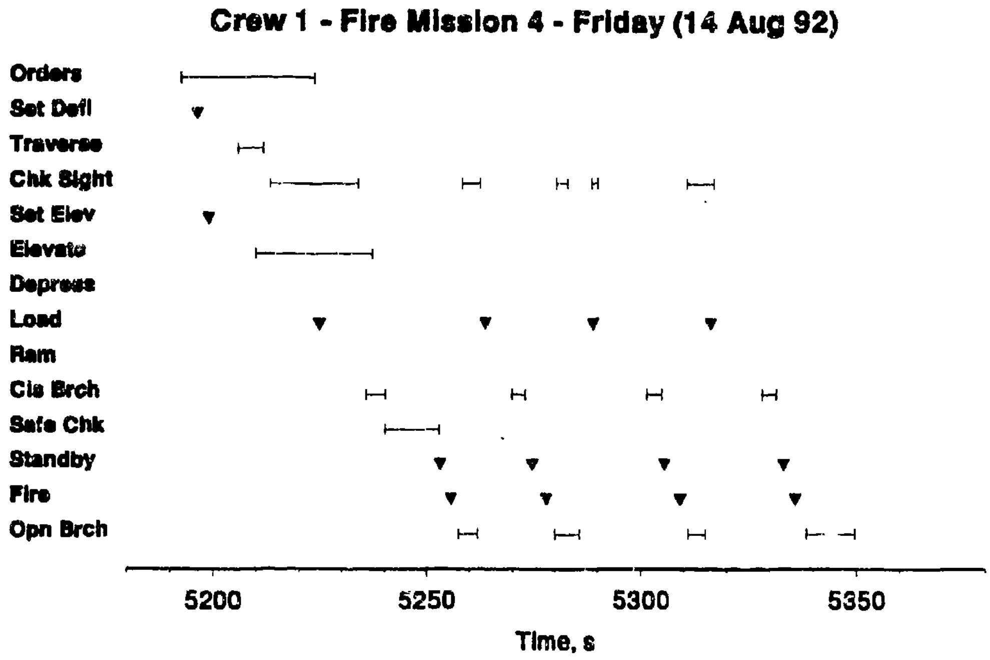


Figure A-4. Crew 1 timelines for fire missions 1 and 2 in BDU.



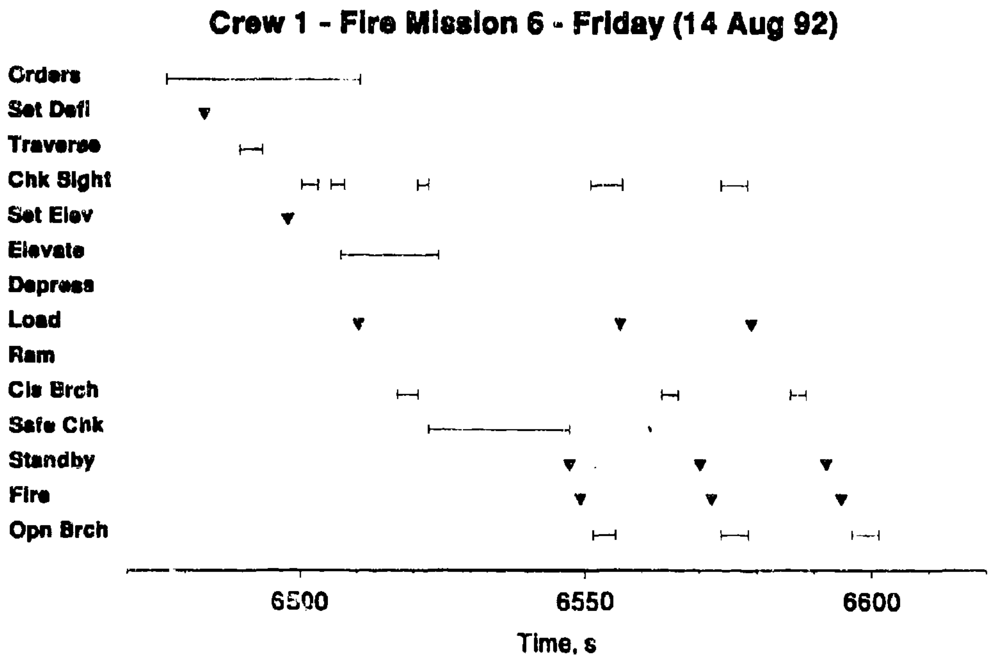
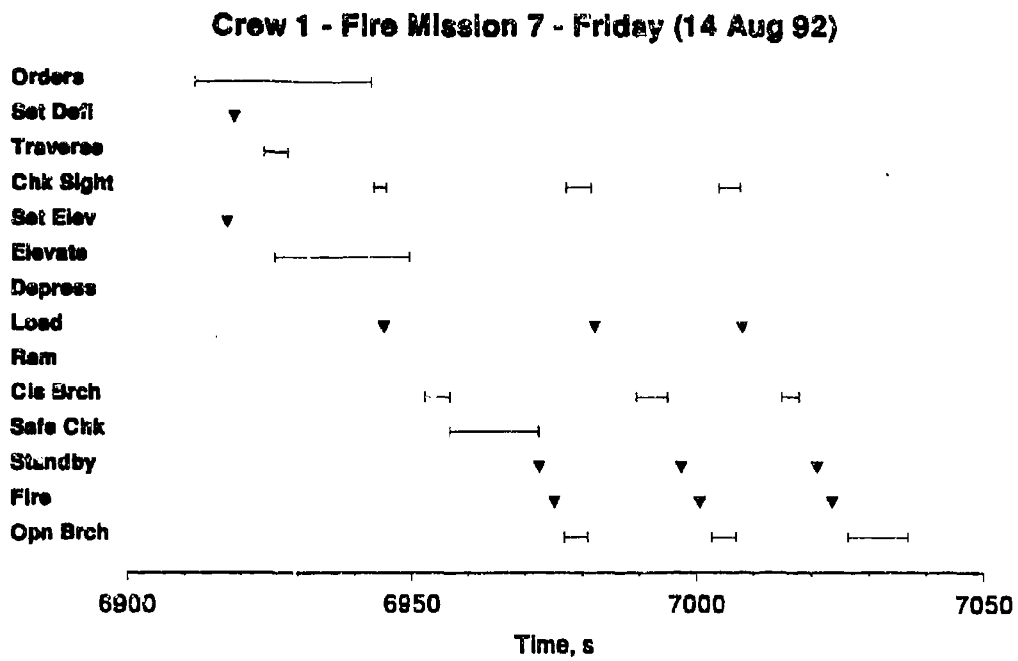


Figure A-5. Crew 1 timelines for fire missions 4 and 6 in BDU.



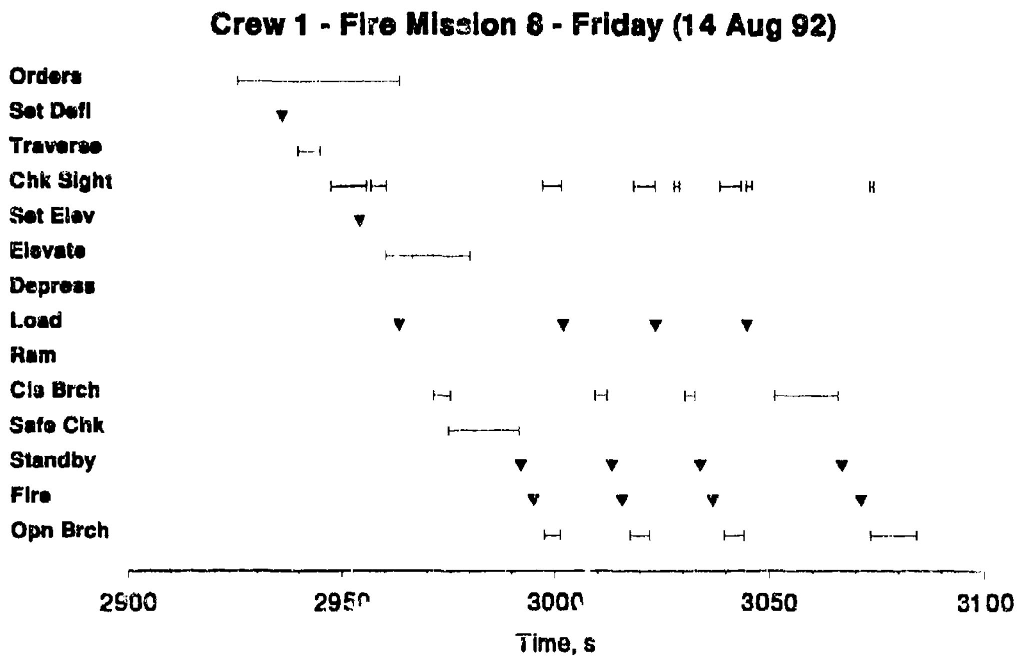
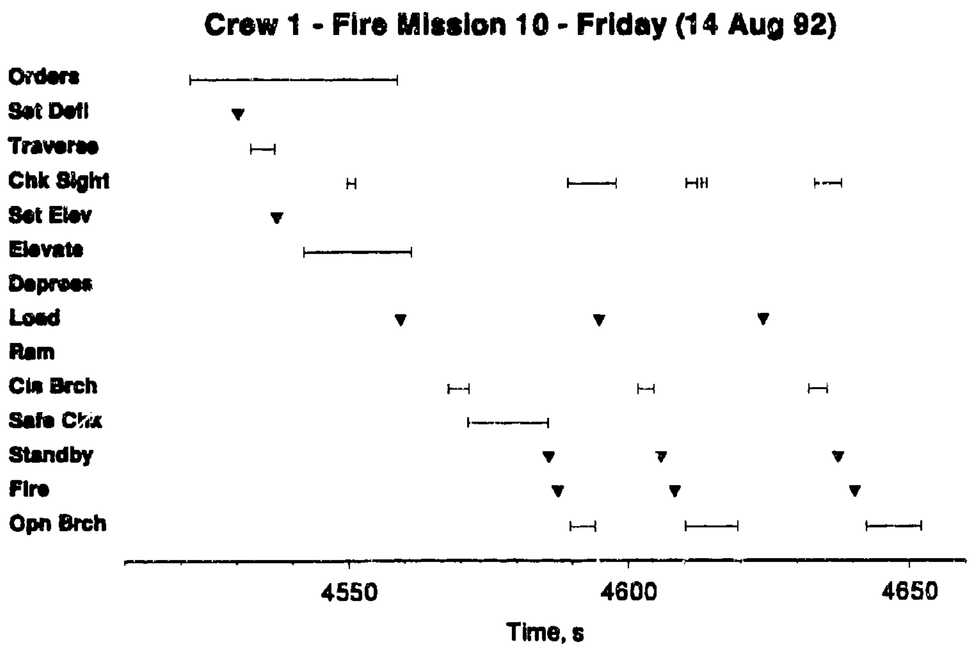


Figure A-6. Crew 1 timelines for fire missions 7 and 8 in BDU.



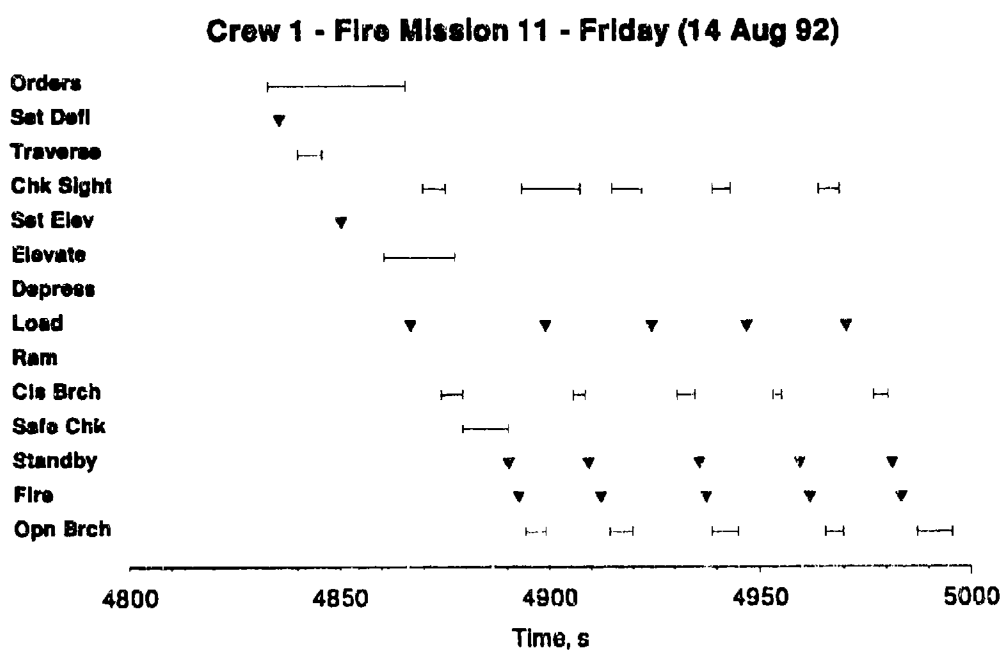
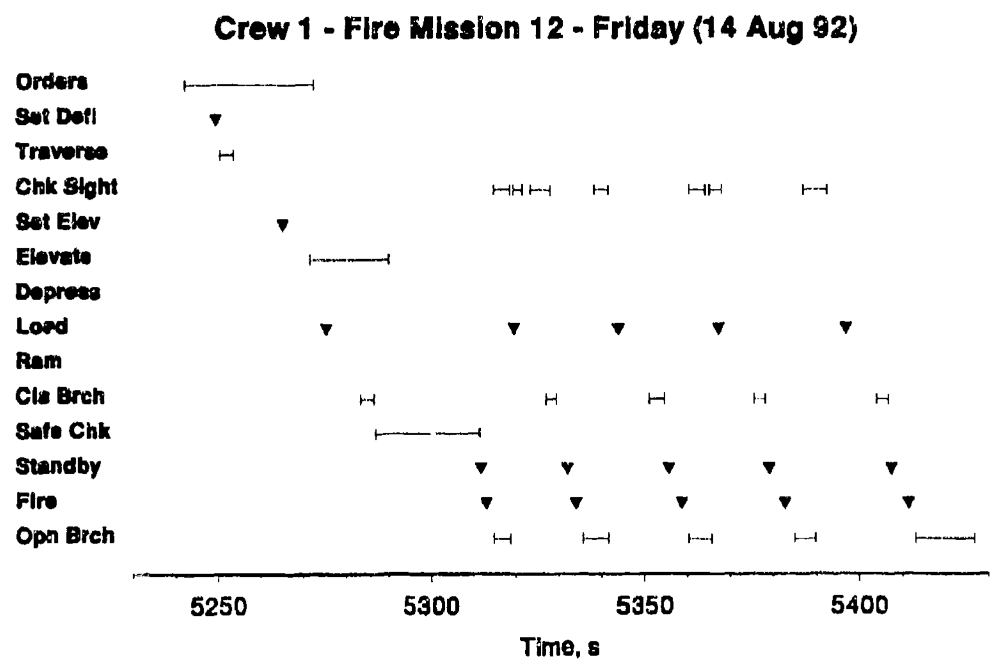


Figure A-7. Crew 1 timelines for fire missions 10 and 11 in BDU.



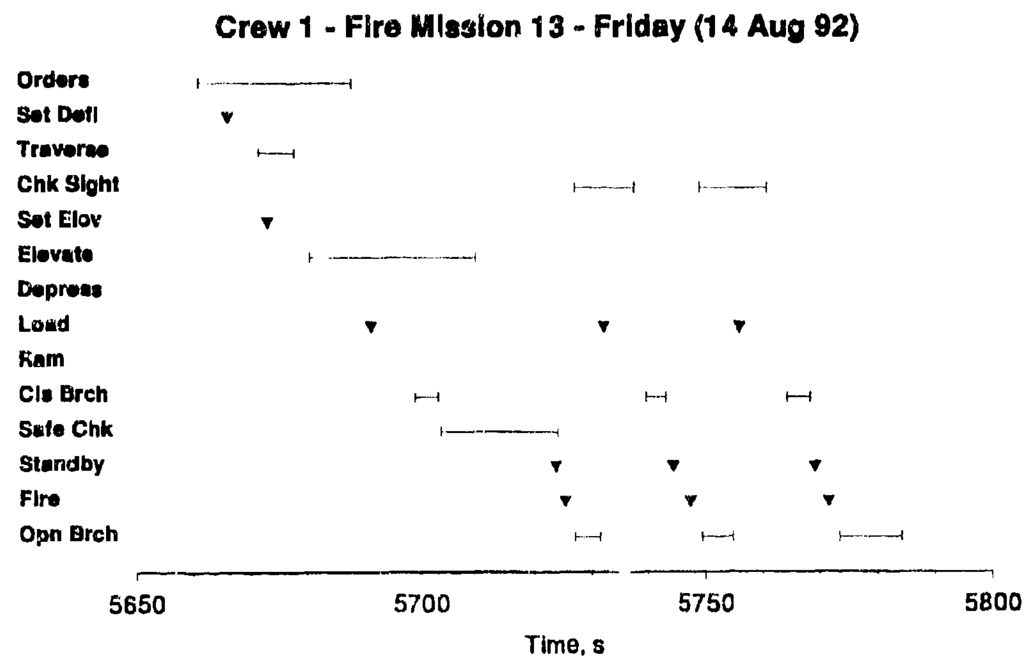
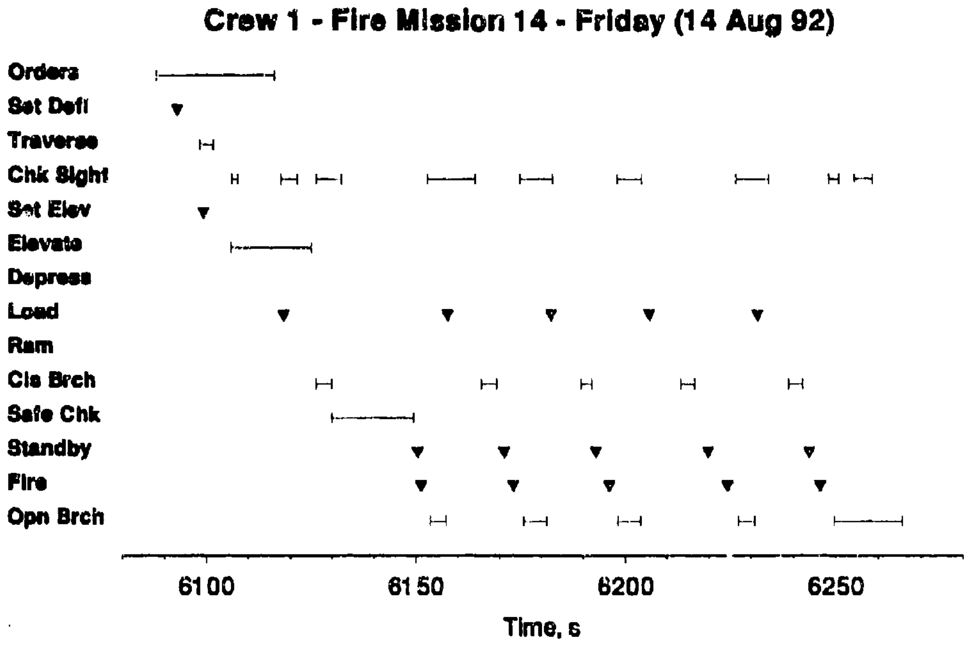


Figure A-8. Crew 1 timelines for firemissions 12 and 13 in BDU.



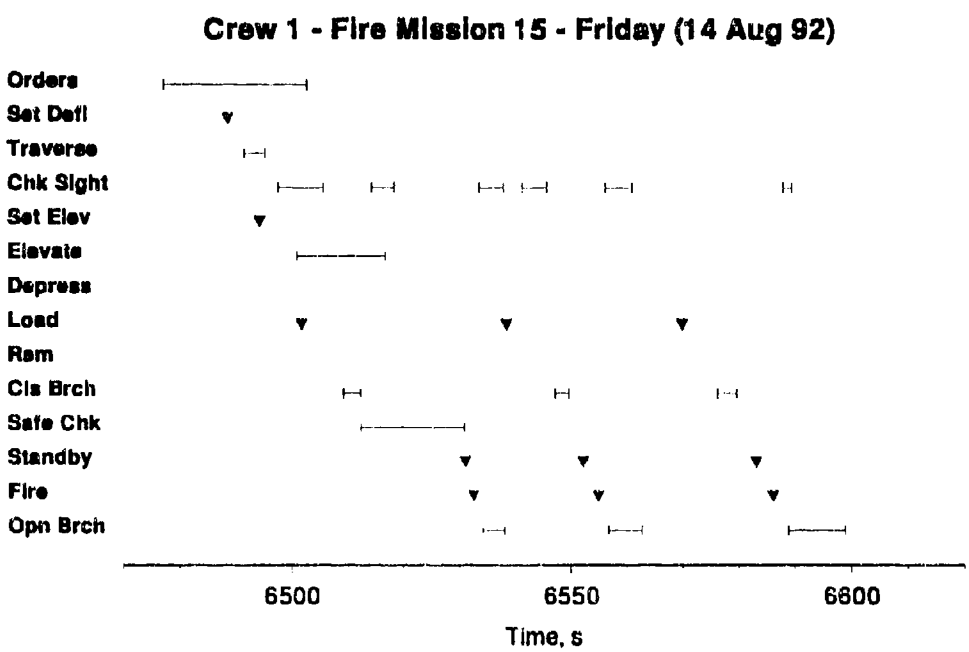
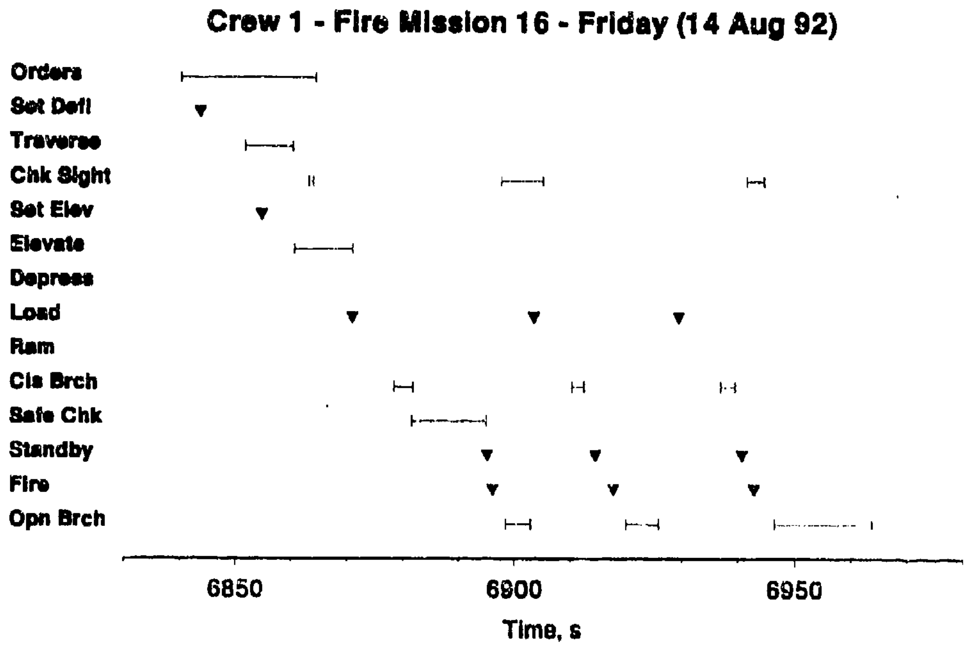


Figure A-9. Crew 1 timelines for fire missions 14 and 15 in BDU.



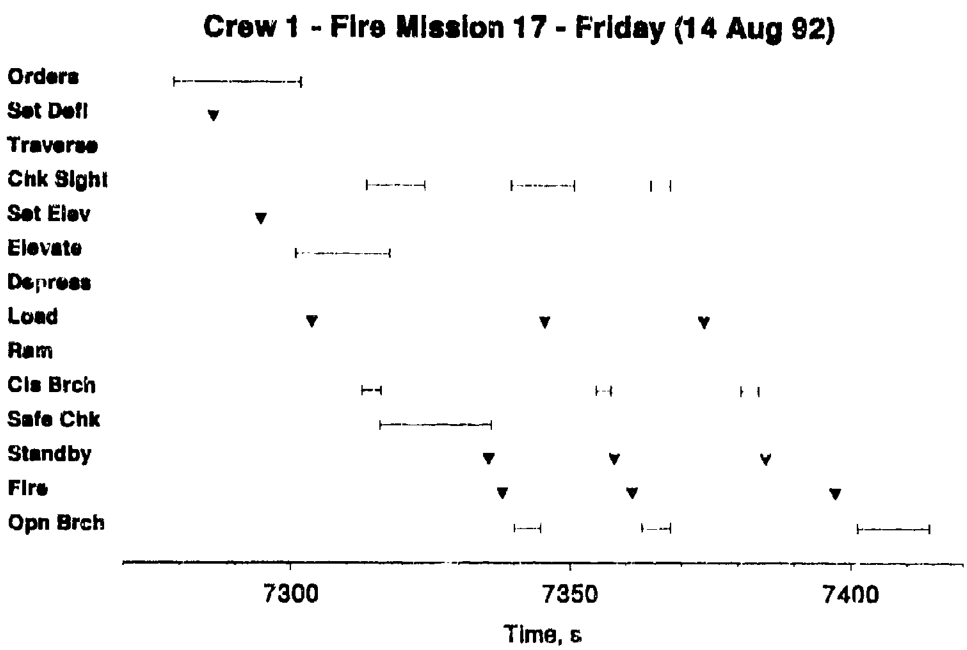
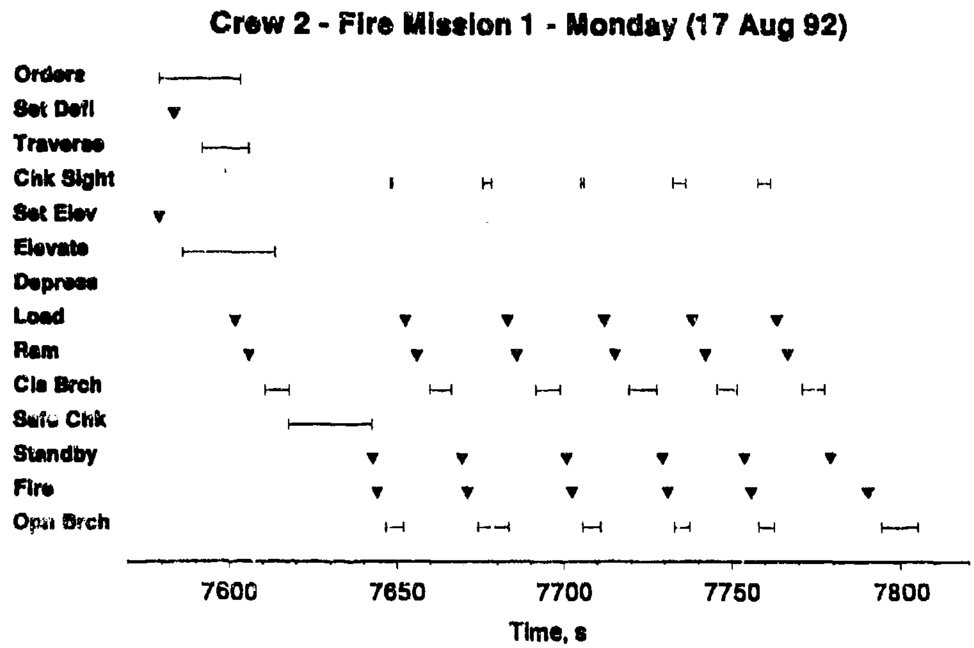


Figure A-10. Crew 1 timelines for fire missions 16 and 17 in BDU.



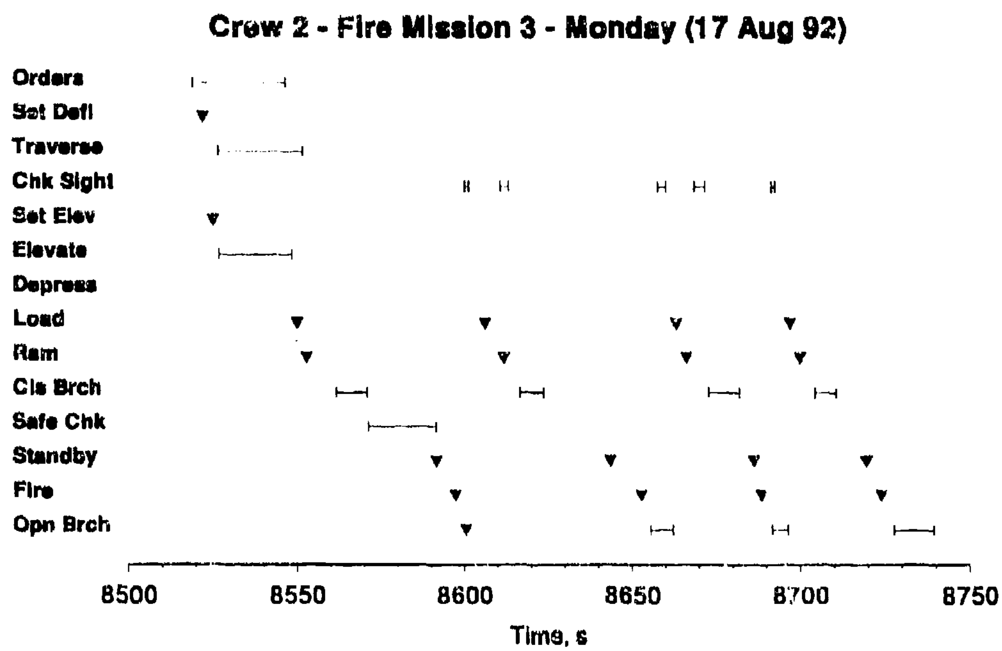
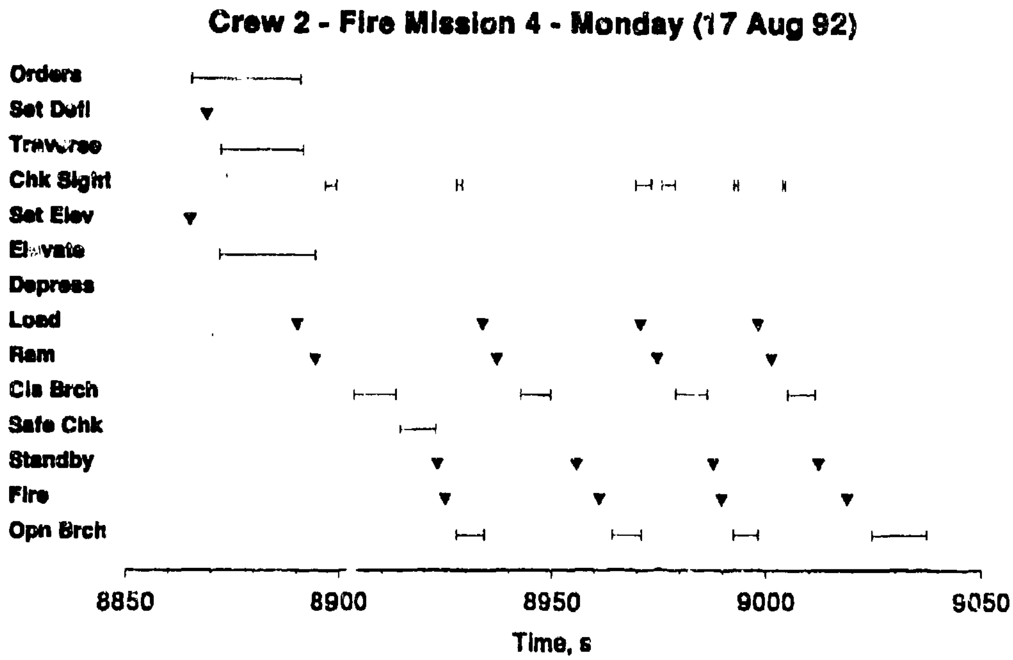


Figure A-11. Crew 2 timelines for fire missions 1 and 3 in BDU.



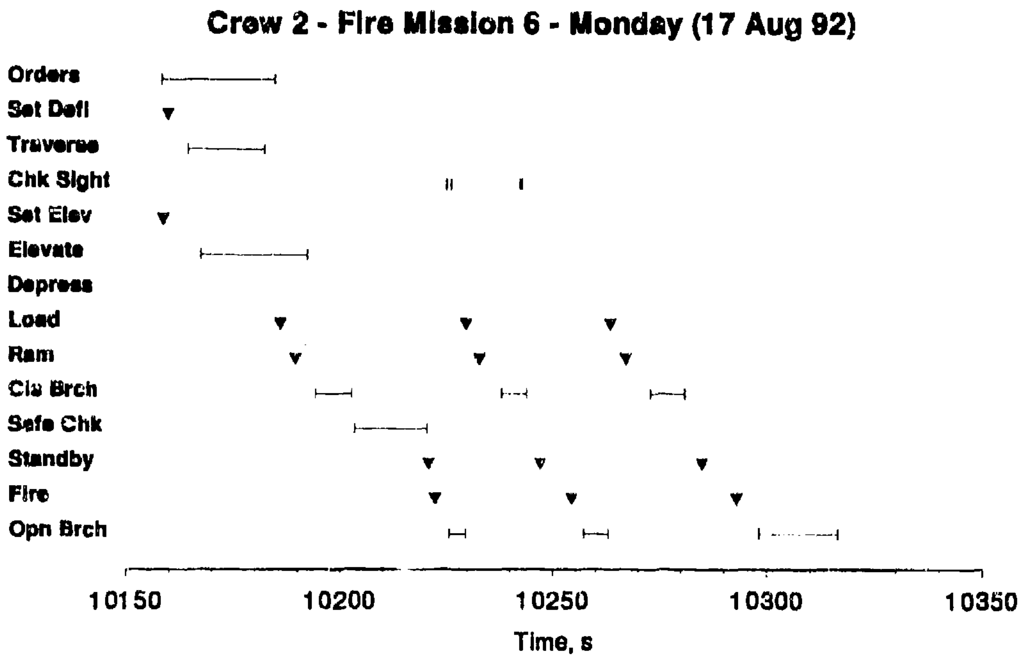
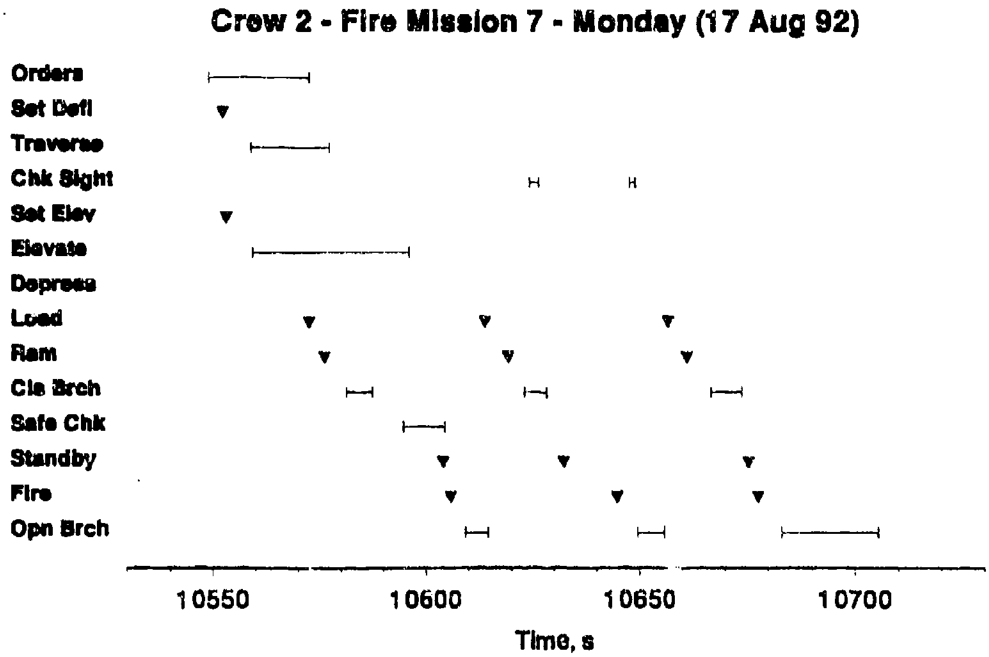


Figure A-12. Crew 2 timelines for fire missions 4 and 6 in BDU.



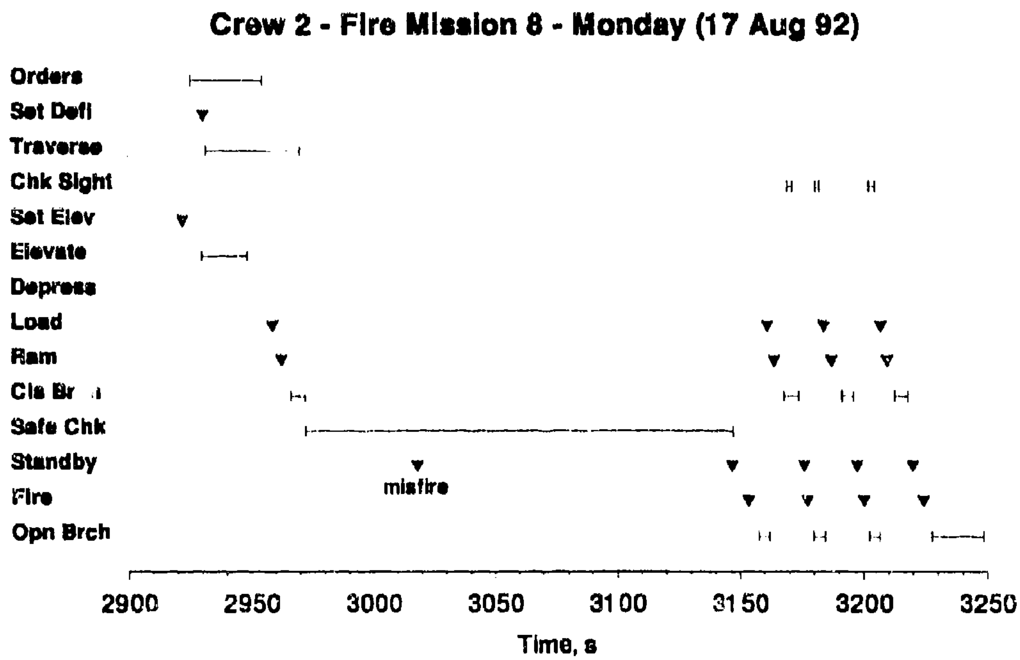
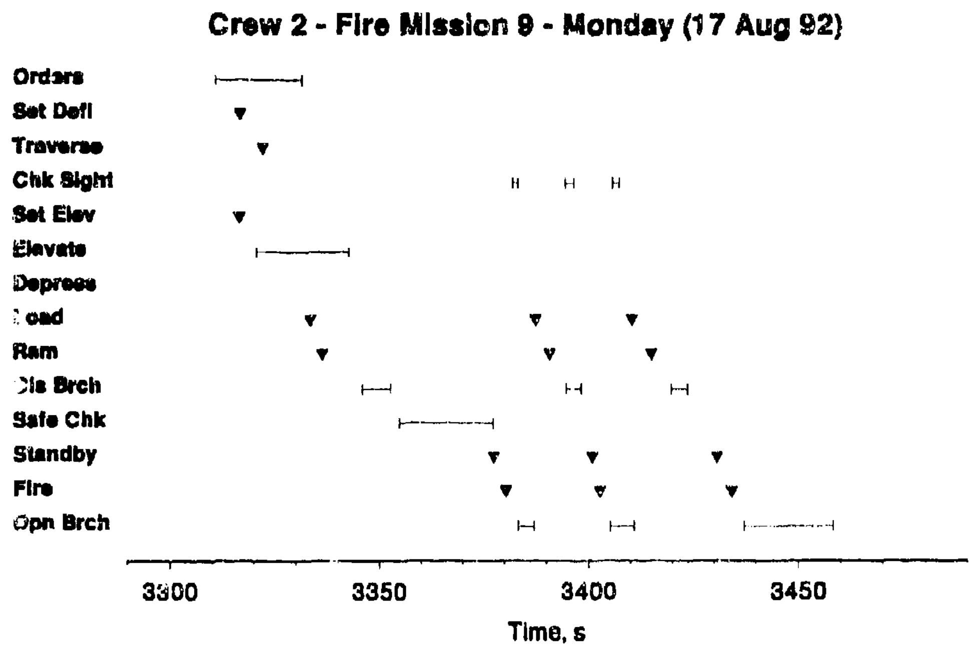


Figure A-13. Crew 2 timelines for fire missions 7 and 8 in BDU.



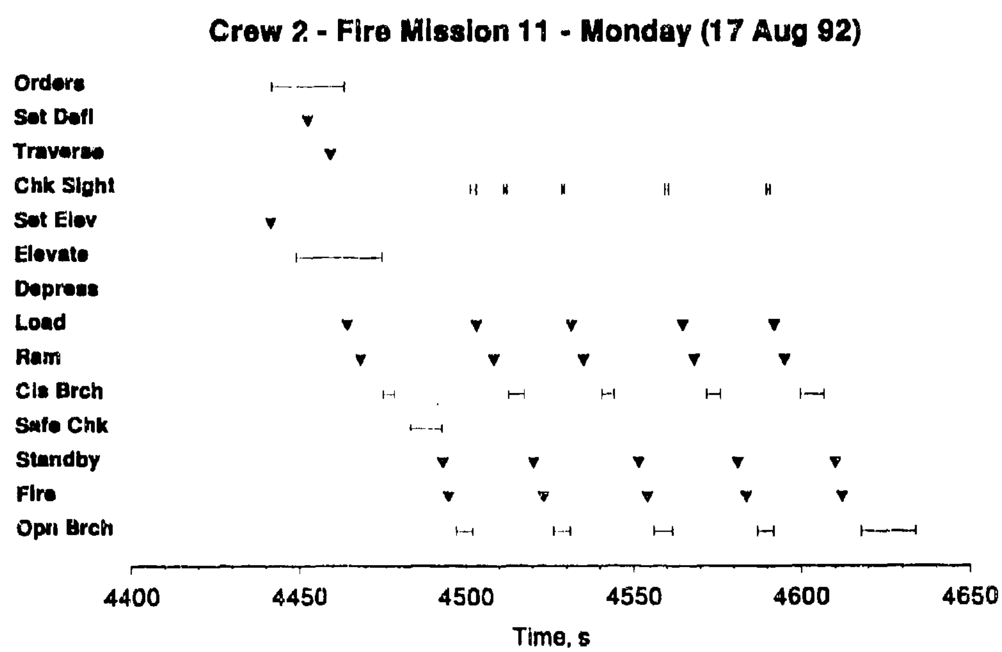
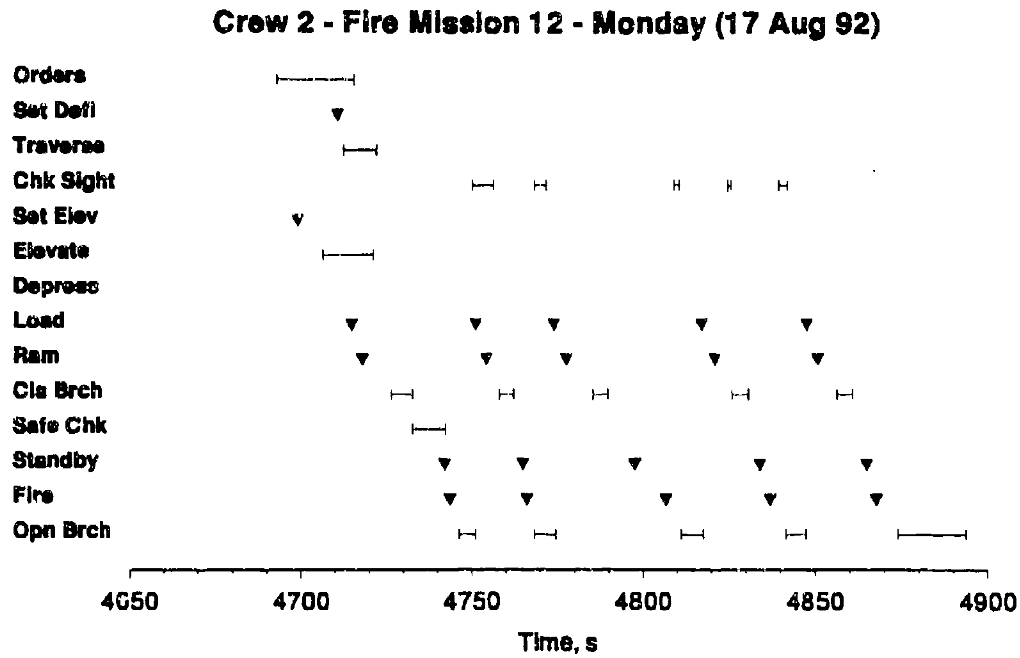


Figure A-14. Crew 2 timelines for fire missions 9 and 11 in BDU.



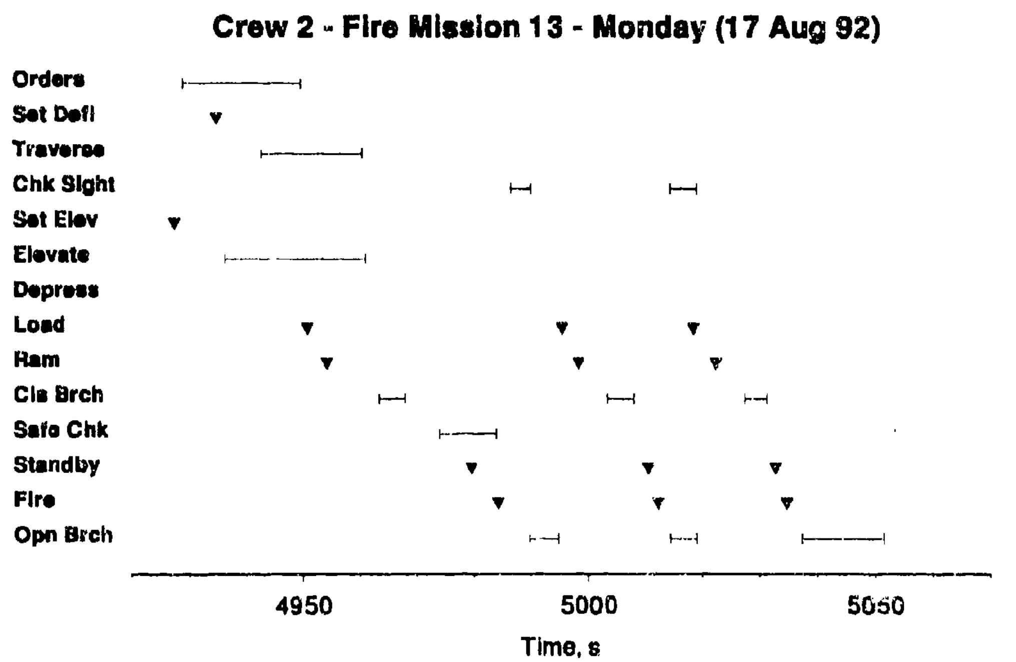
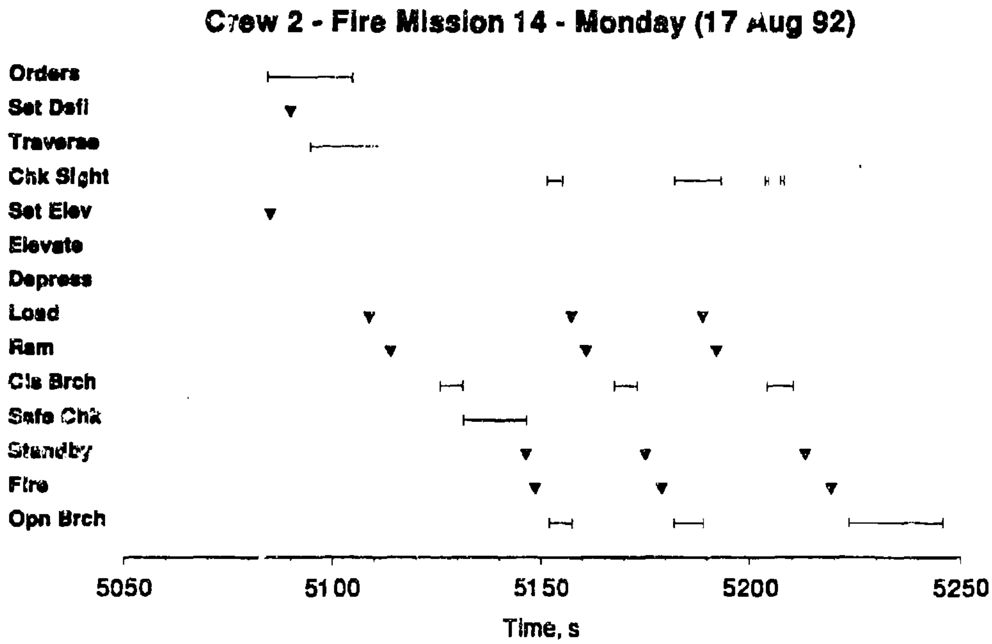


Figure A-15. Crew 2 timelines for fire missions 12 and 13 in BDU.



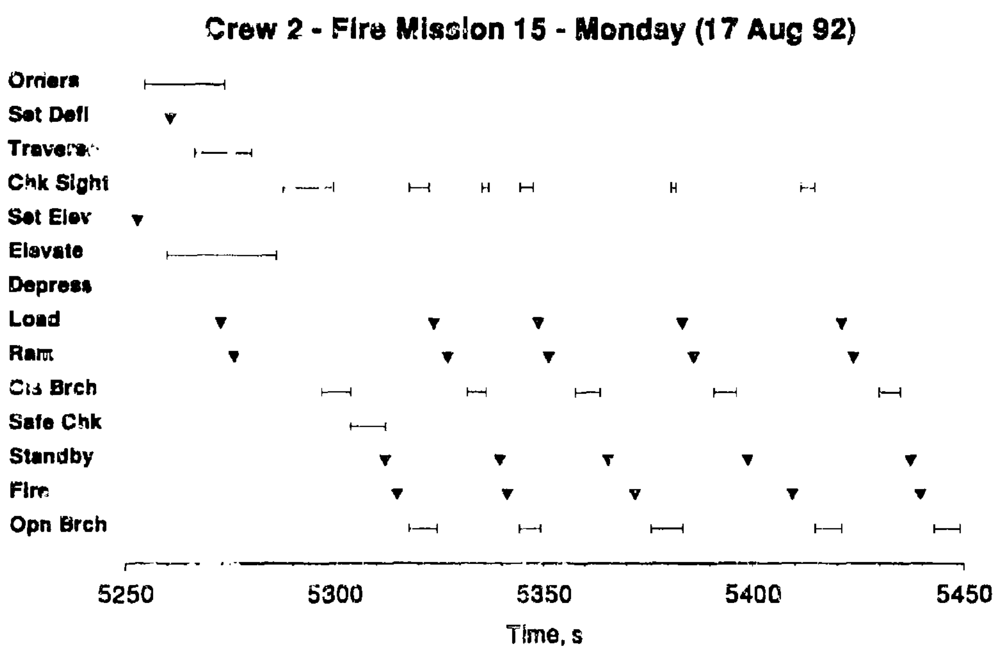


Figure A-16. Crew 2 timelines for fire missions 14 and 15 in BDU.

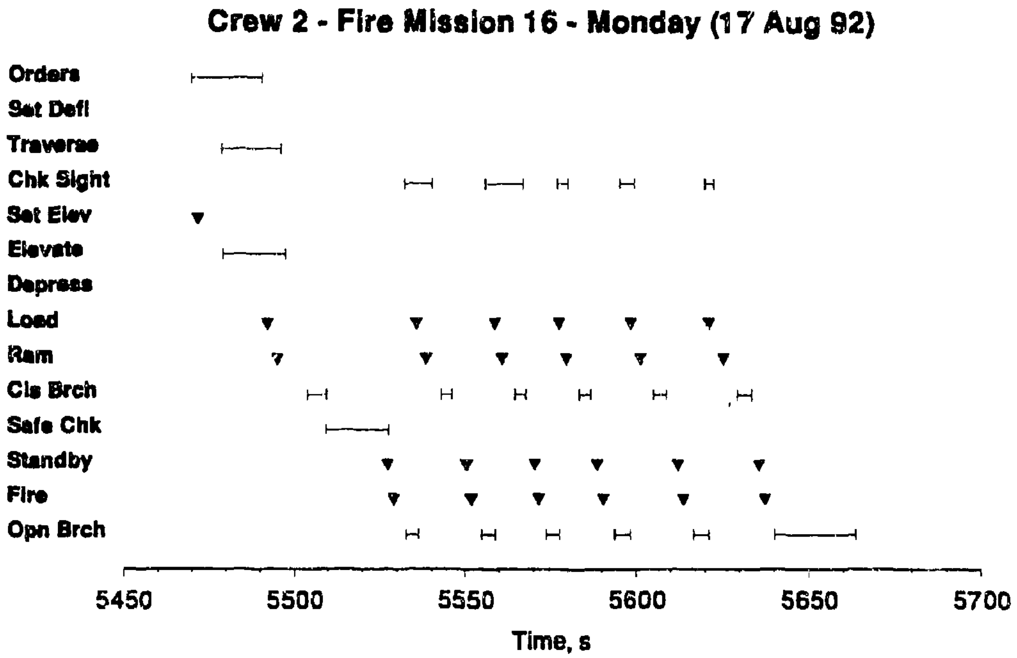
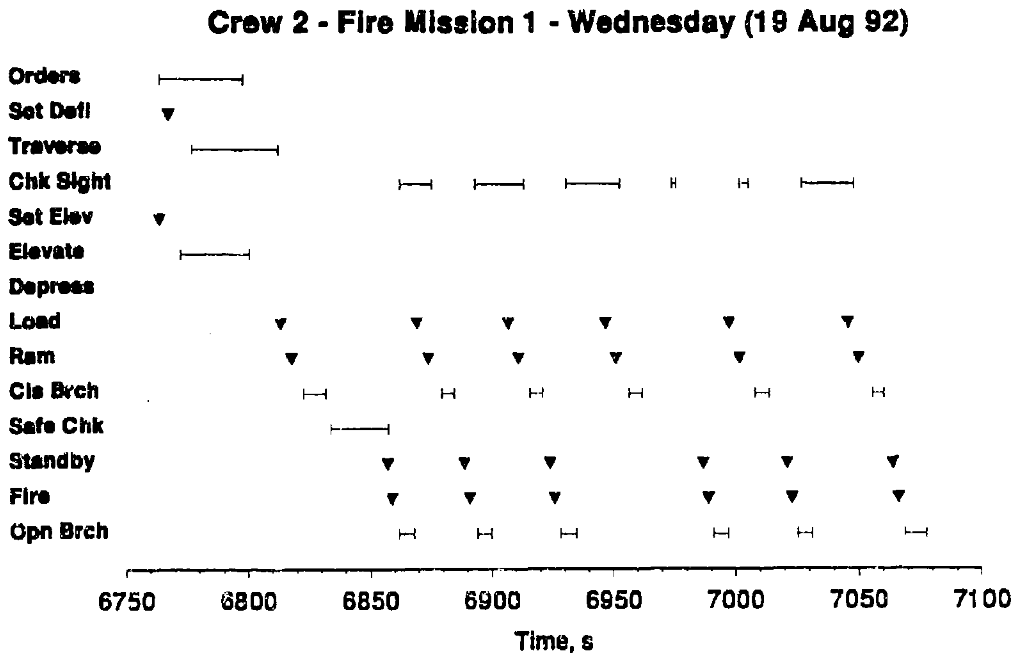


Figure A-17. Crew 2 timelines for fire mission 16 in BDU.



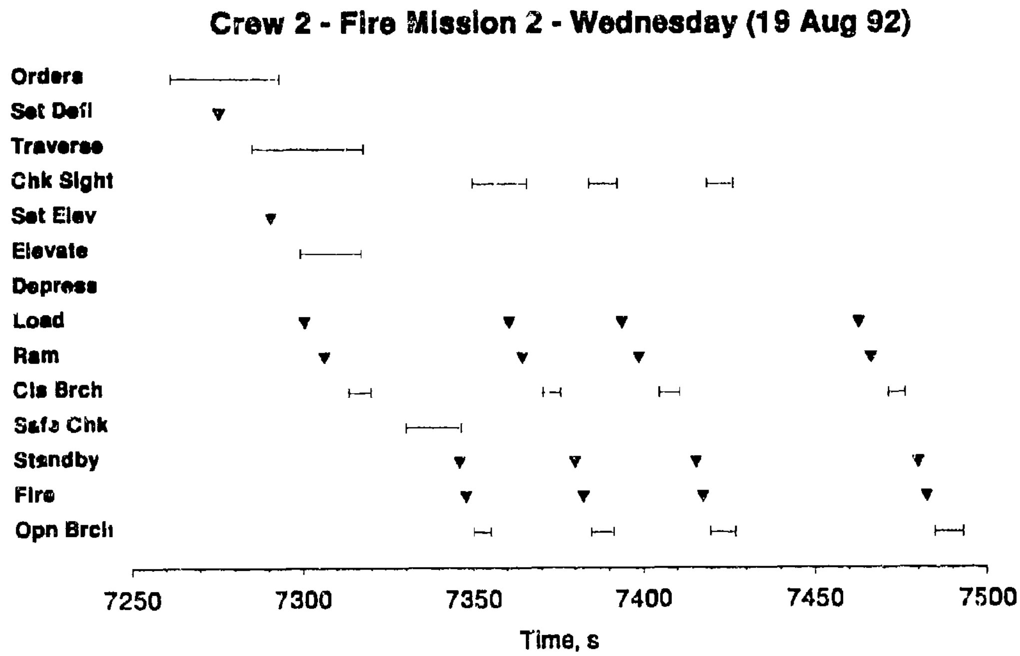
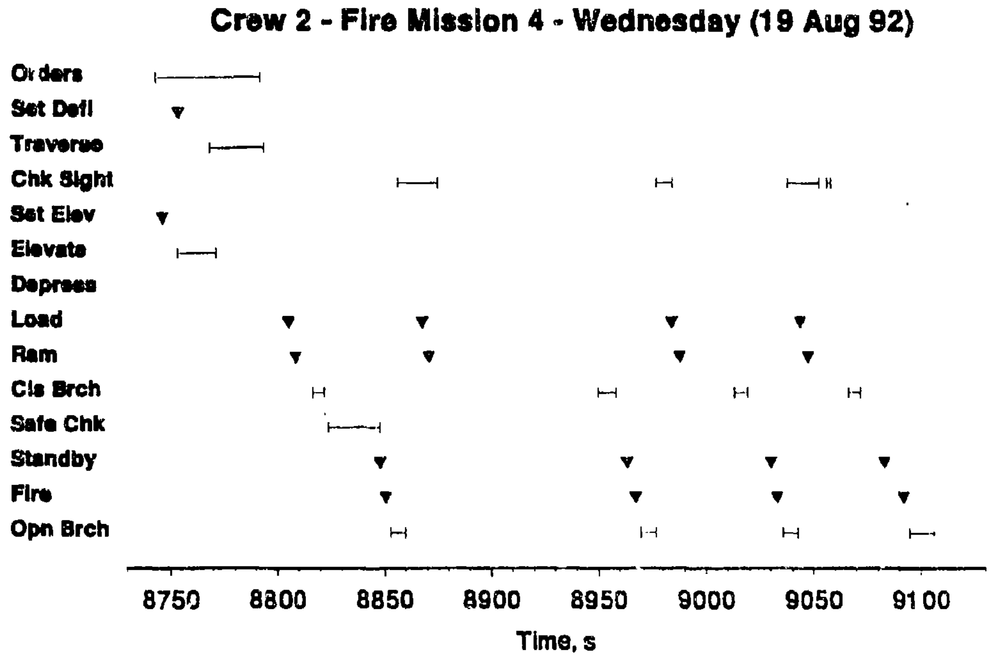


Figure A-18. Crew 2 timelines for fire missions 1 and 2 in MOPP4-S.



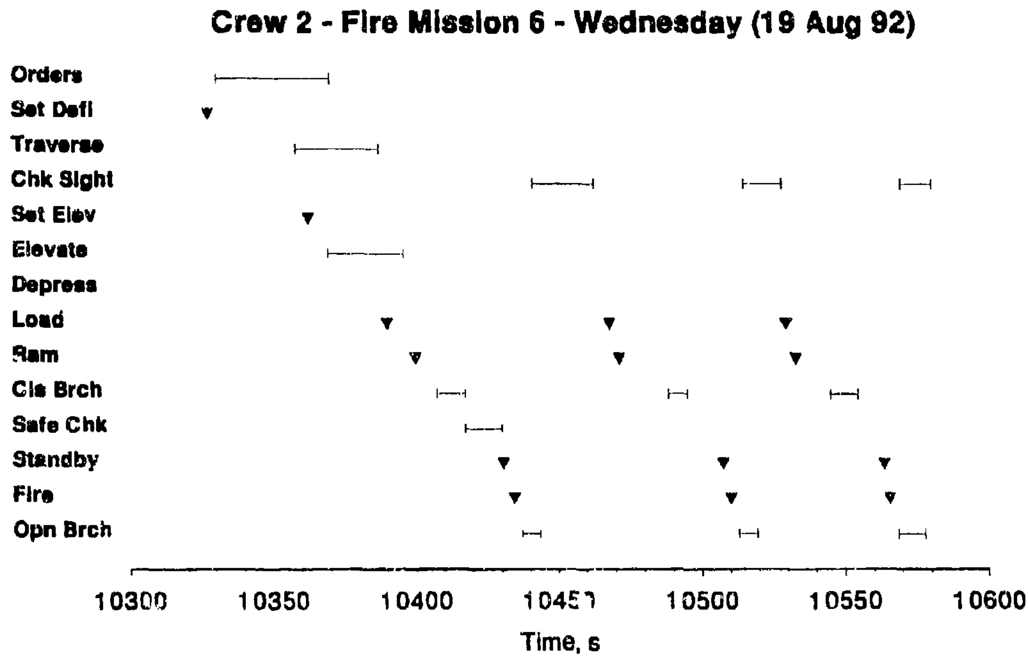
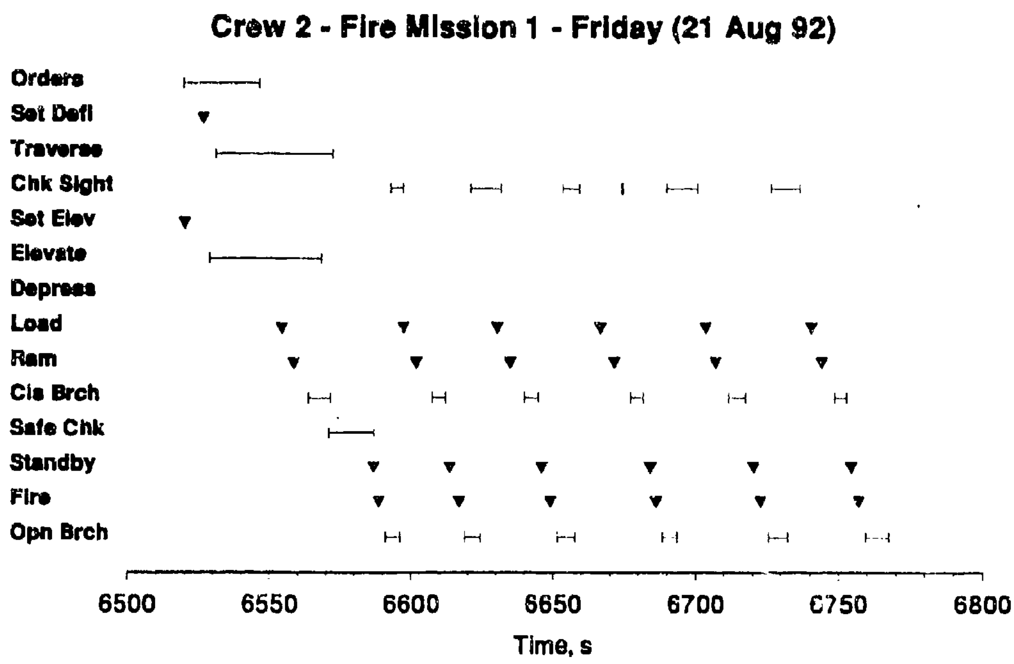


Figure A-19. Crew 2 timelines for fire missions 4 and 6 in MOPP4-S.



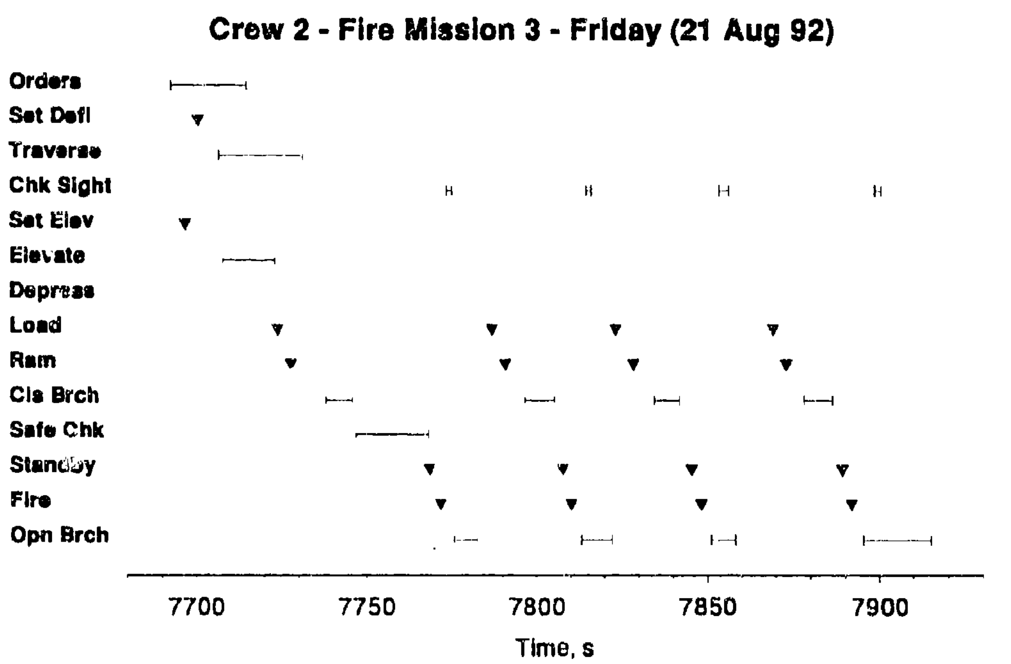
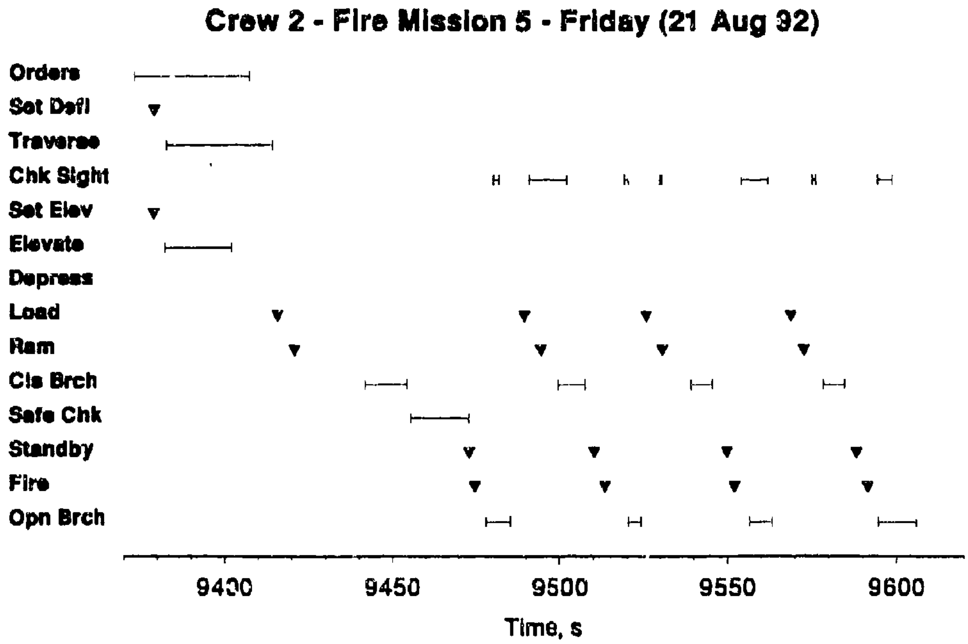


Figure A-20. Crew 2 timelines for fire missions 1 and 3 in MOPP4-R.



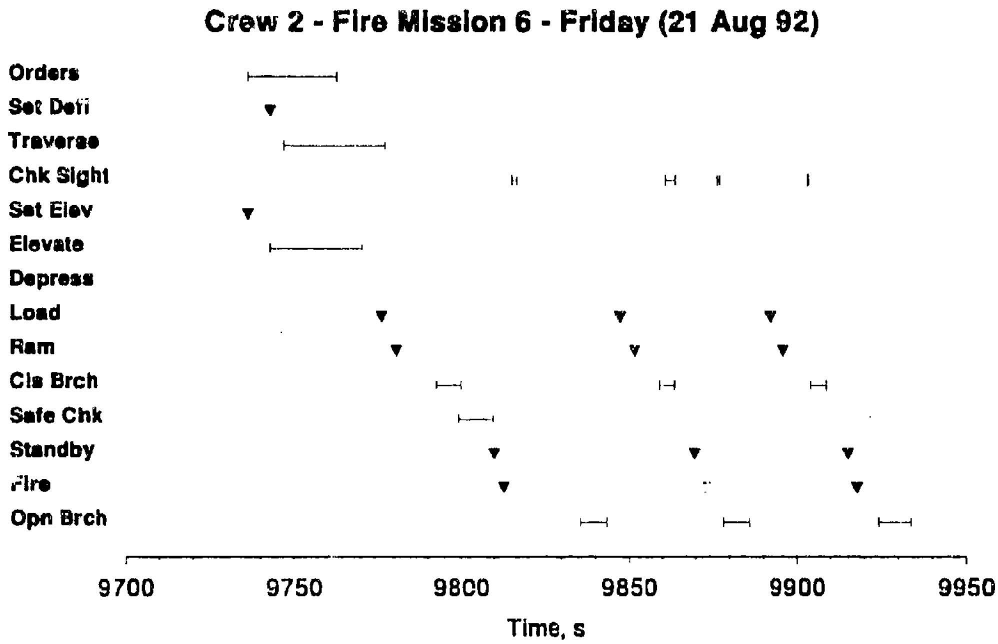
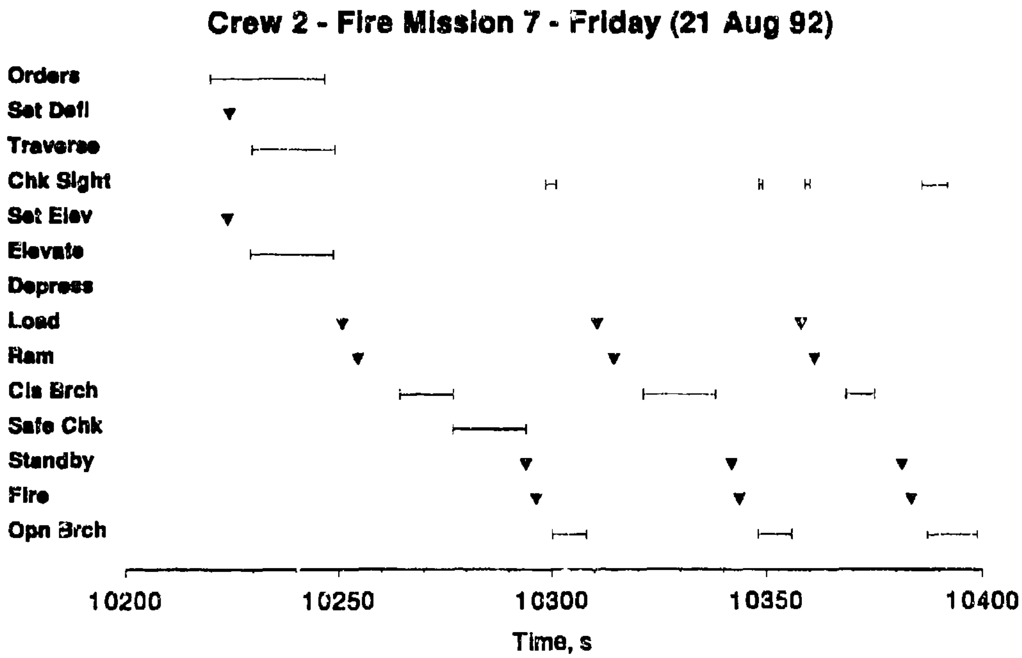


Figure A-21. Crew 2 timelines for fire missions 5 and 6 in MOPP4-R.



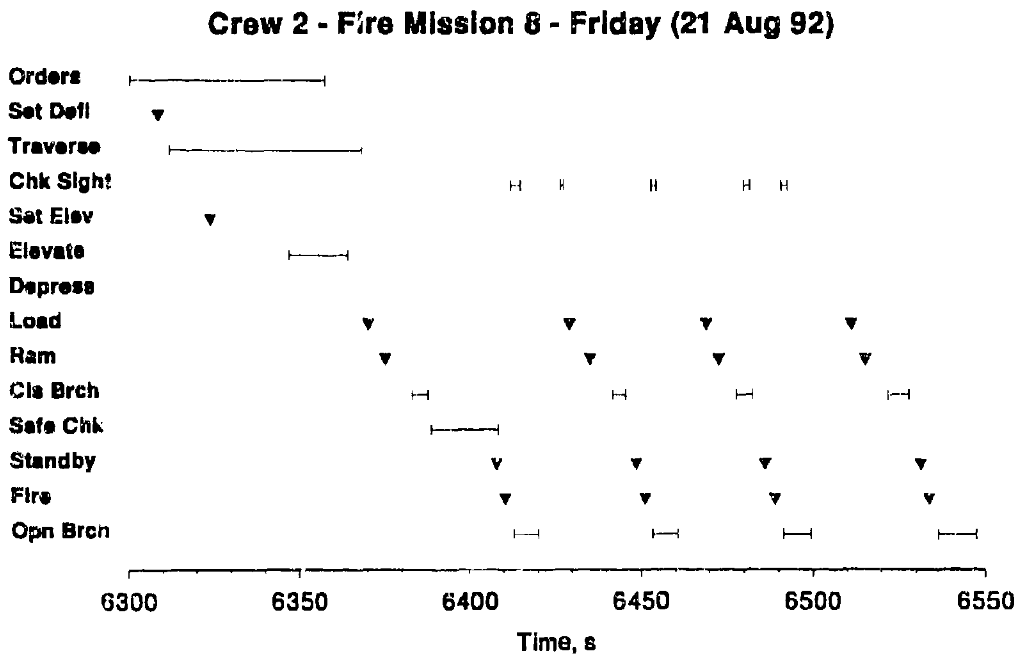
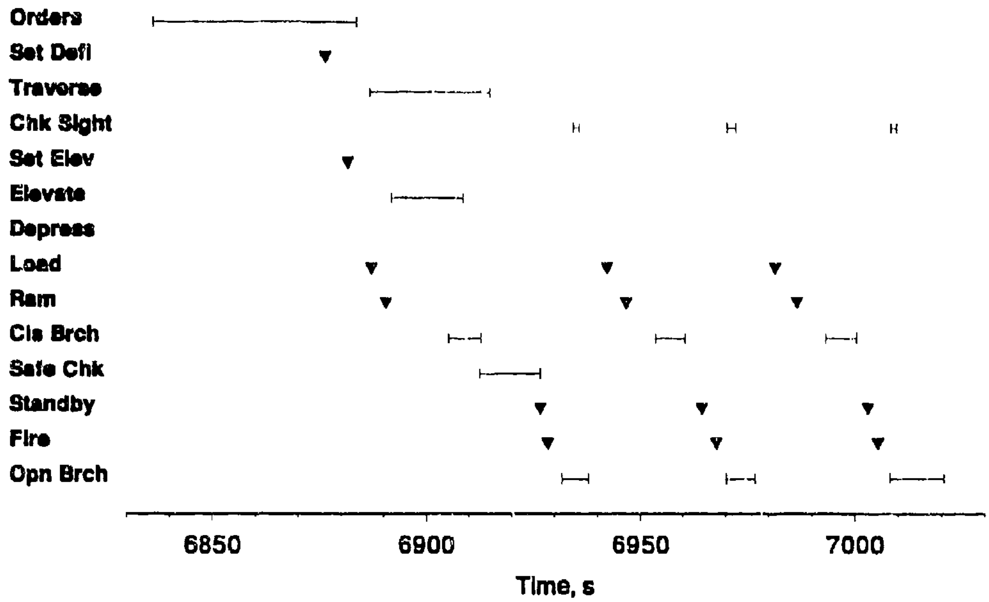


Figure A-22. Crew 2 timelines for fire missions 7 and 8 in MOPP 4-R.

Crew 2 - Fire Mission 9 - Friday (21 Aug 92)



Crew 2 - Fire Mission 10 - Friday (21 Aug 92)

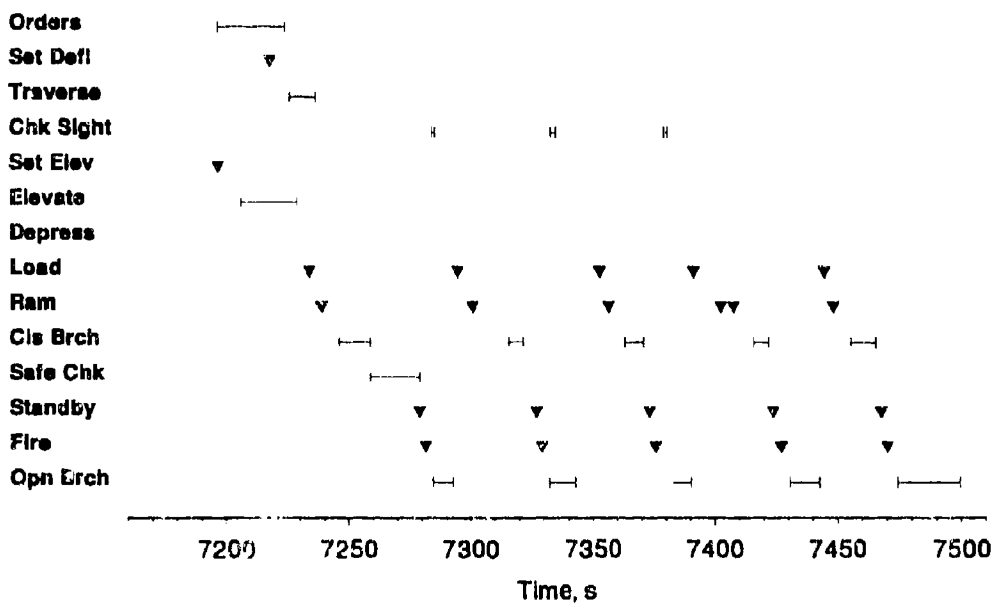
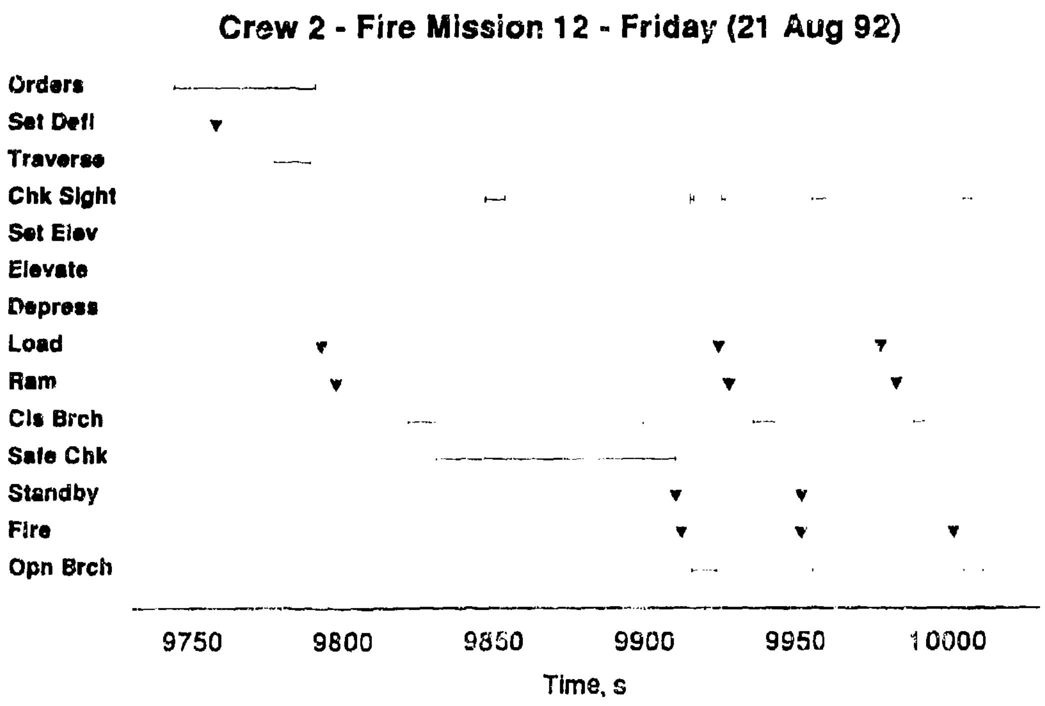


Figure A-23. Crew 2 timelines for fire missions 9 and 10 in MOPP4-R.



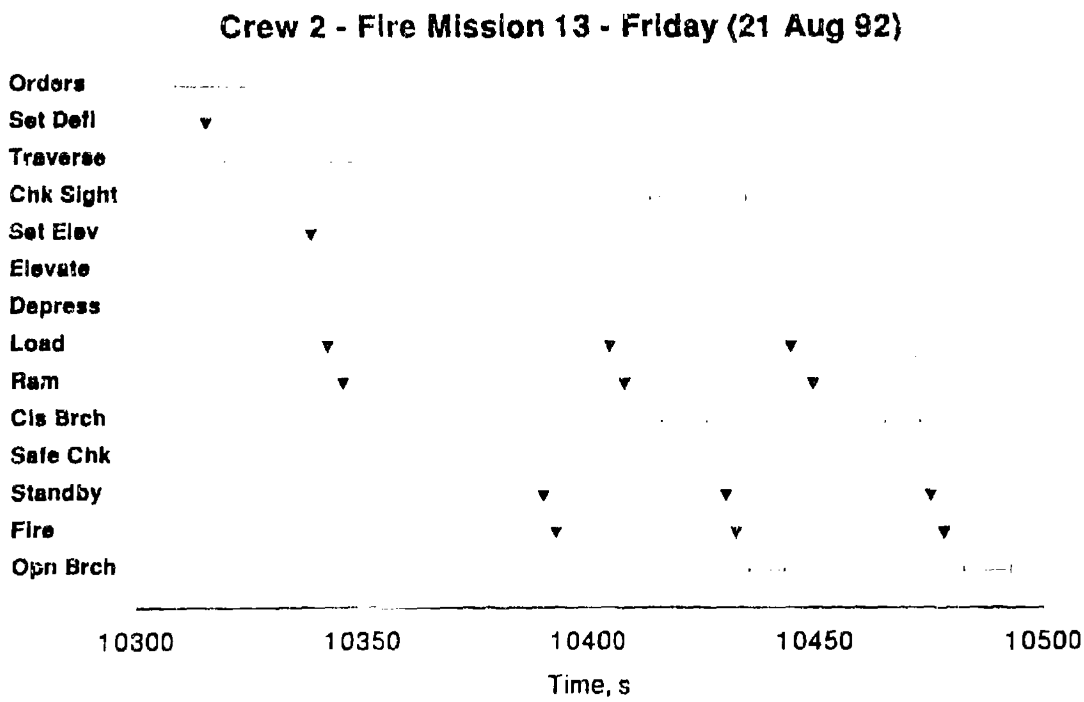
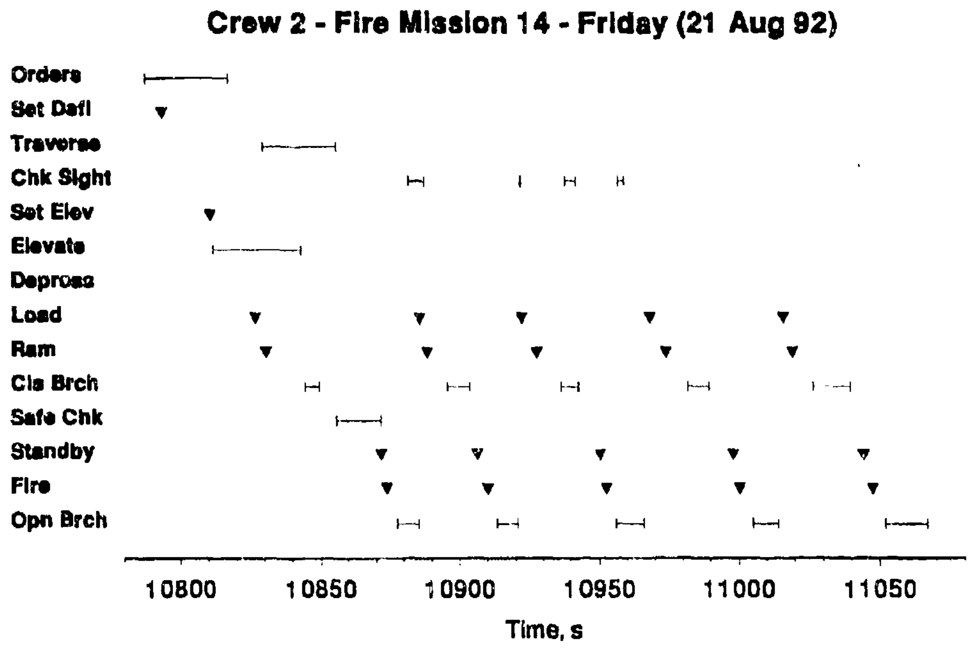


Figure A-24. Crew 2 timelines for fire missions 12 and 13 in MOPP4-R.



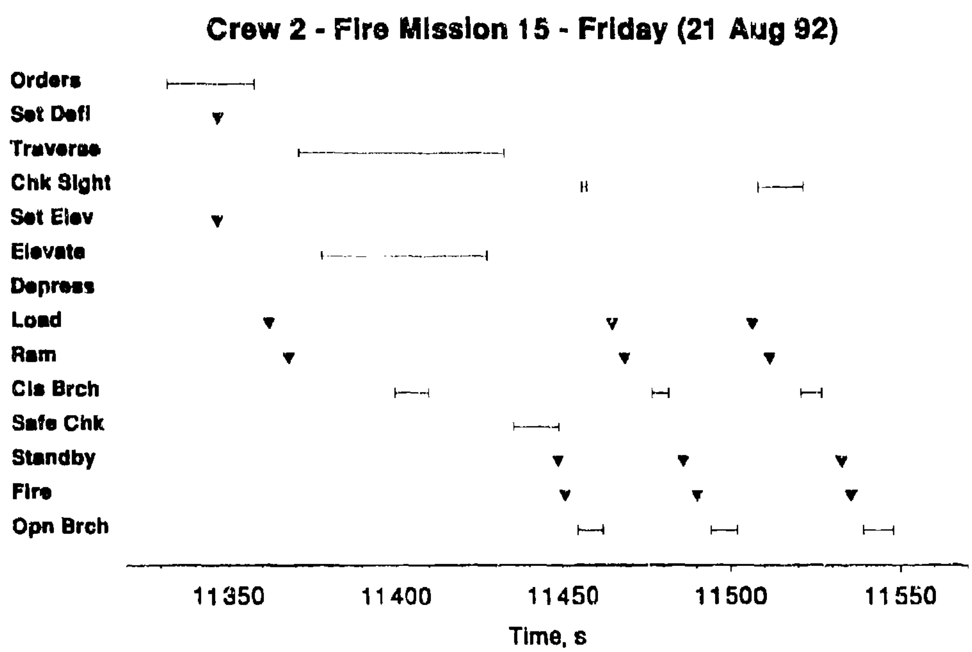
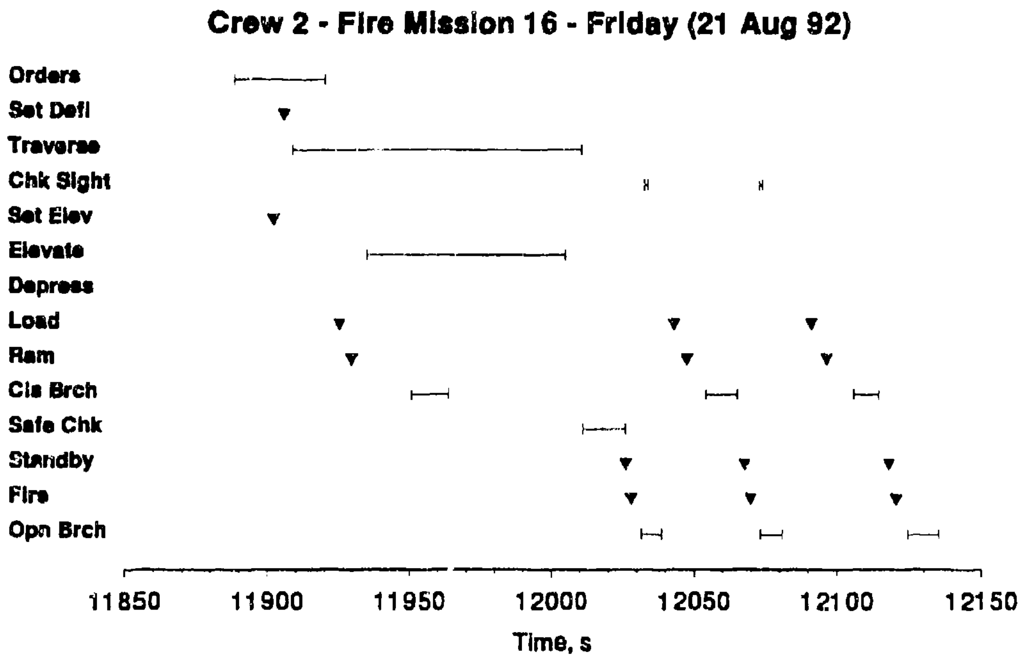


Figure A-25. Crew 2 timelines for fire missions 14 and 15 in MOPP4-R.



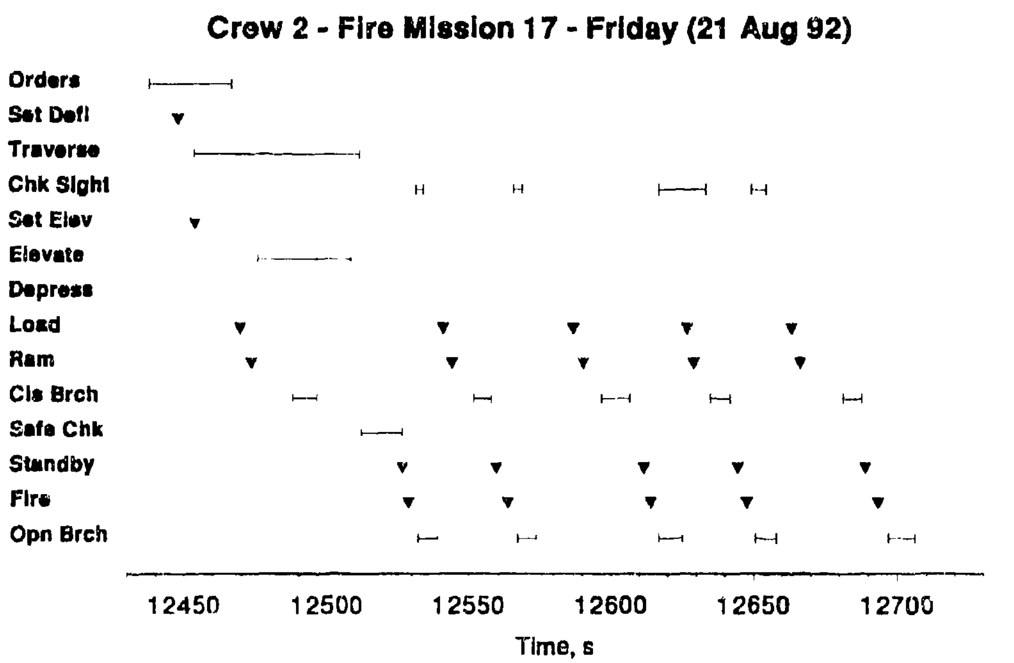
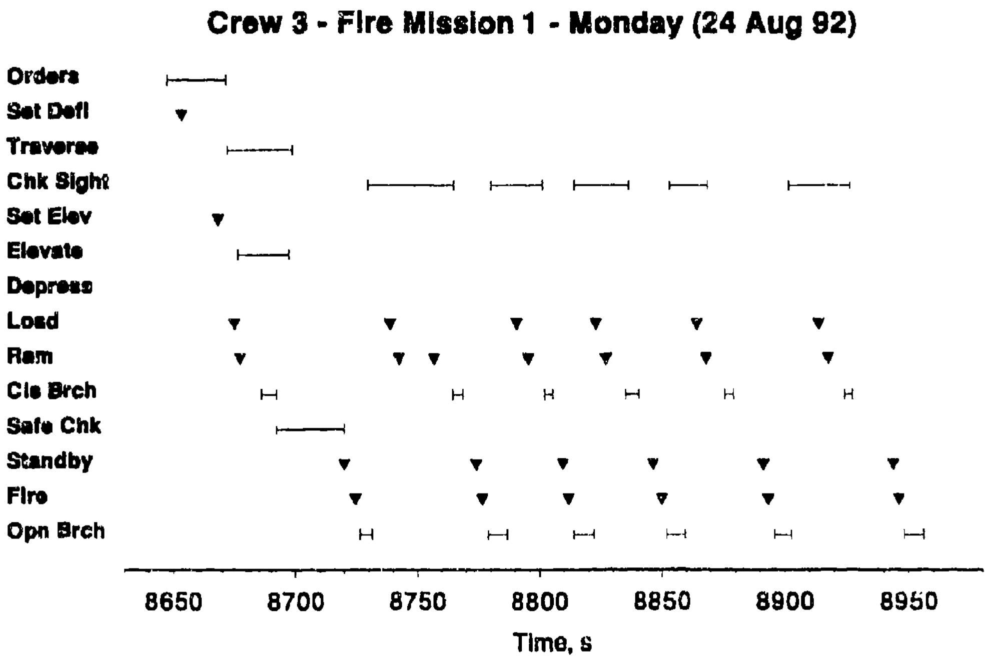


Figure A-26. Crew 2 timelines for fire missions 16 and 17 in MOPP4-R.



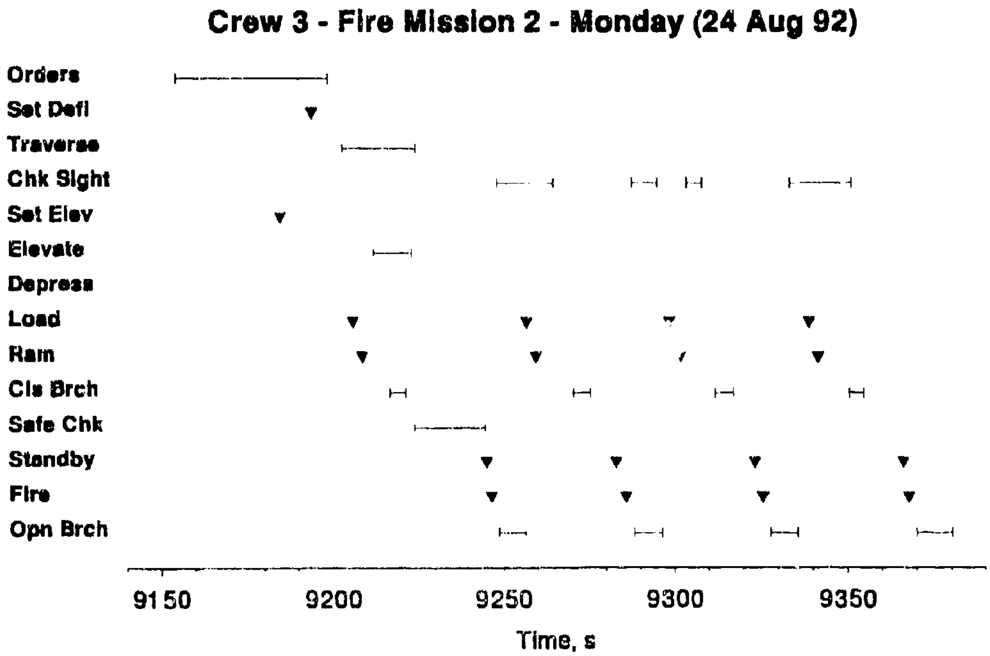
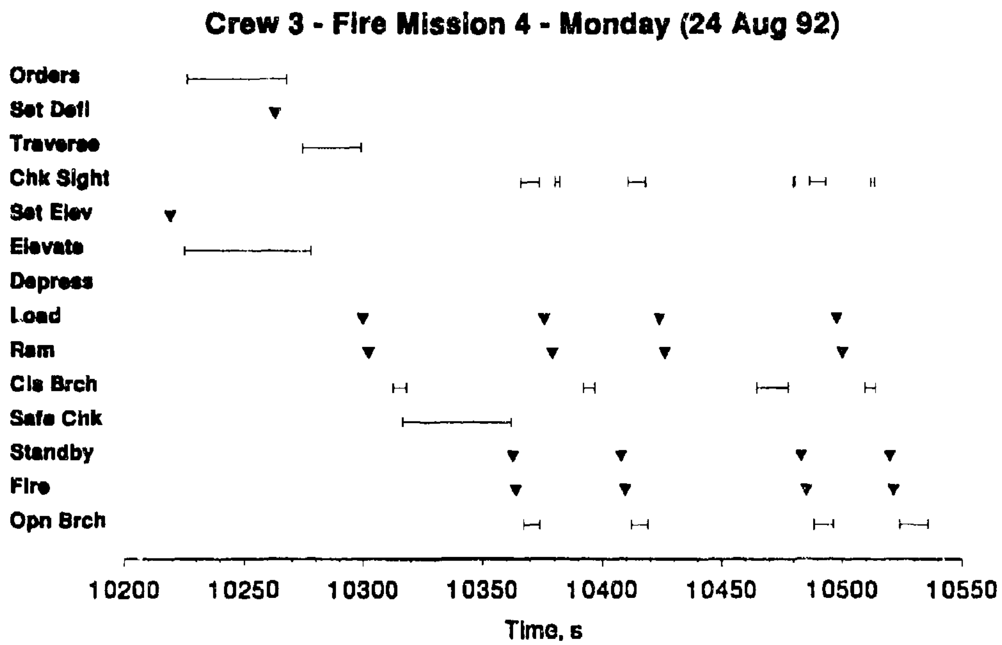


Figure A-27. Crew 3 timelines for fire missions 1 and 2 in MOPP4-S.



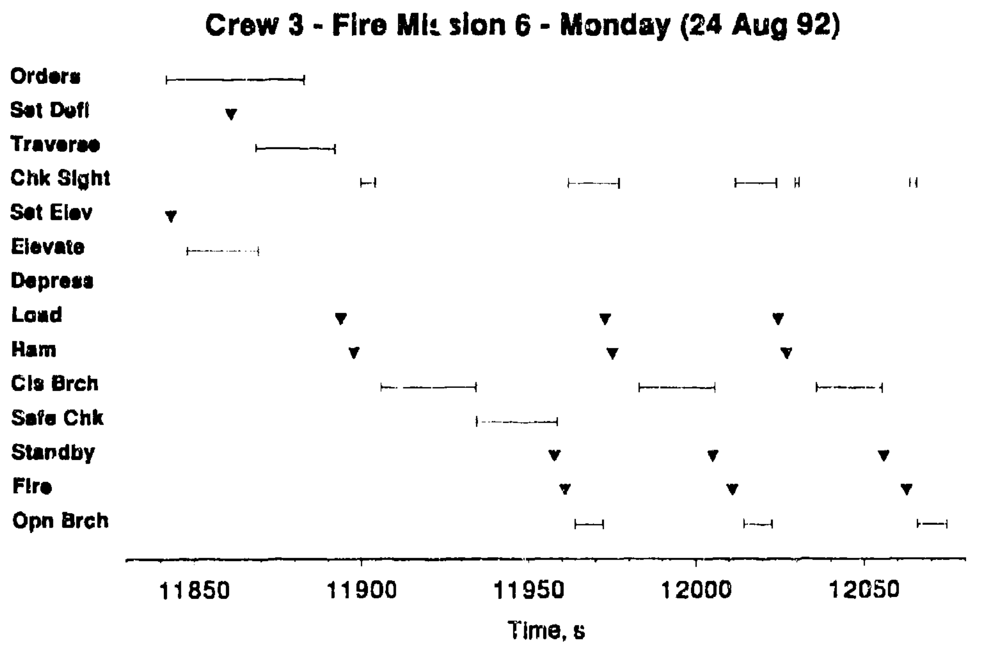
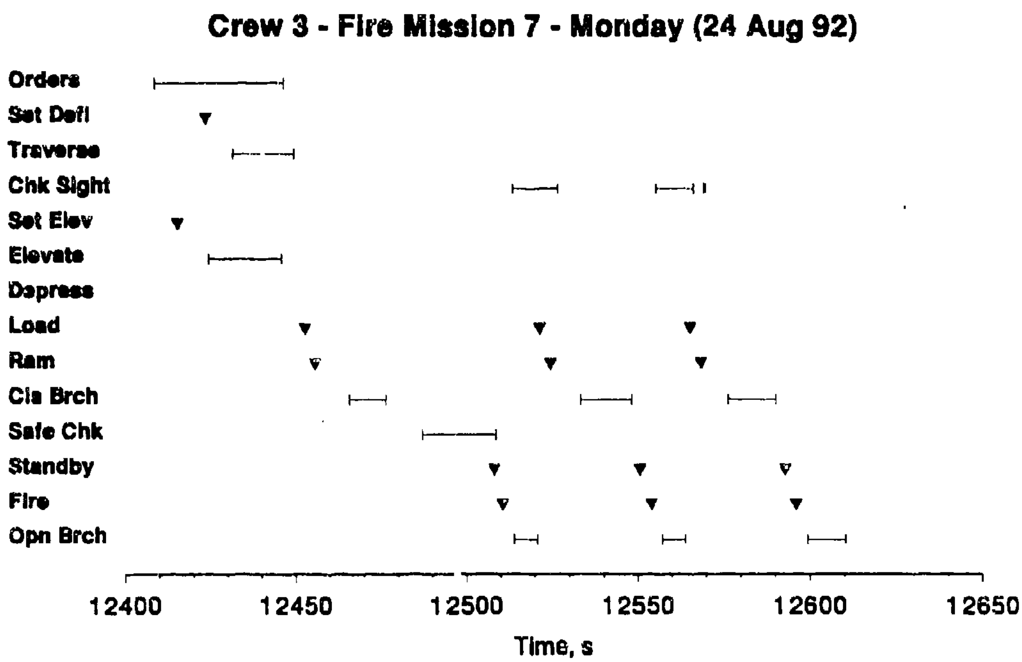


Figure A-28. Crew 3 timelines for fire missions 4 and 6 in MOPP4-S.



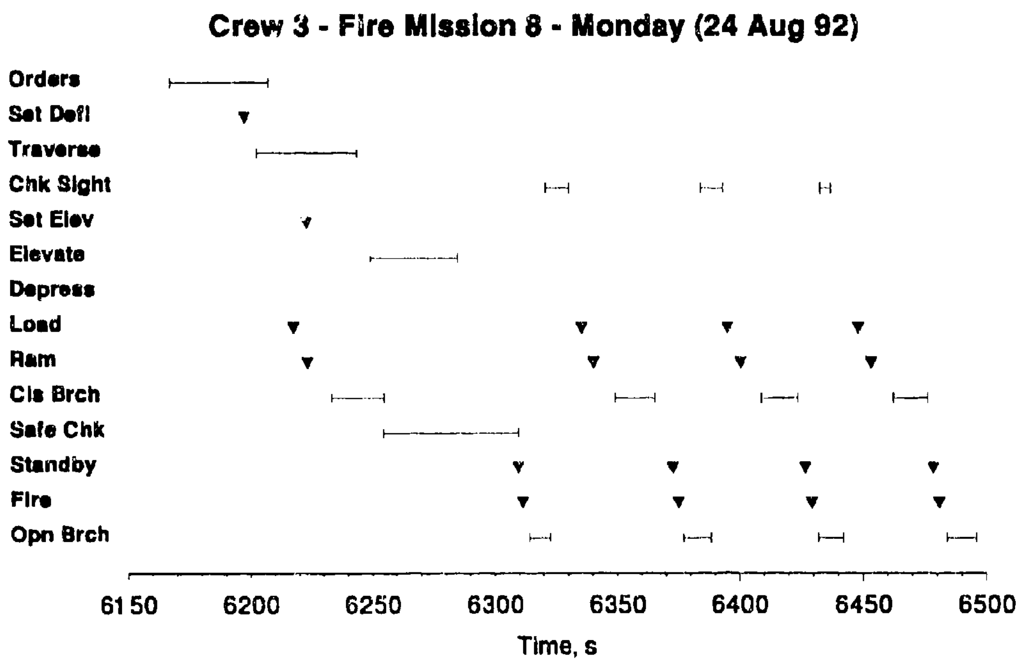
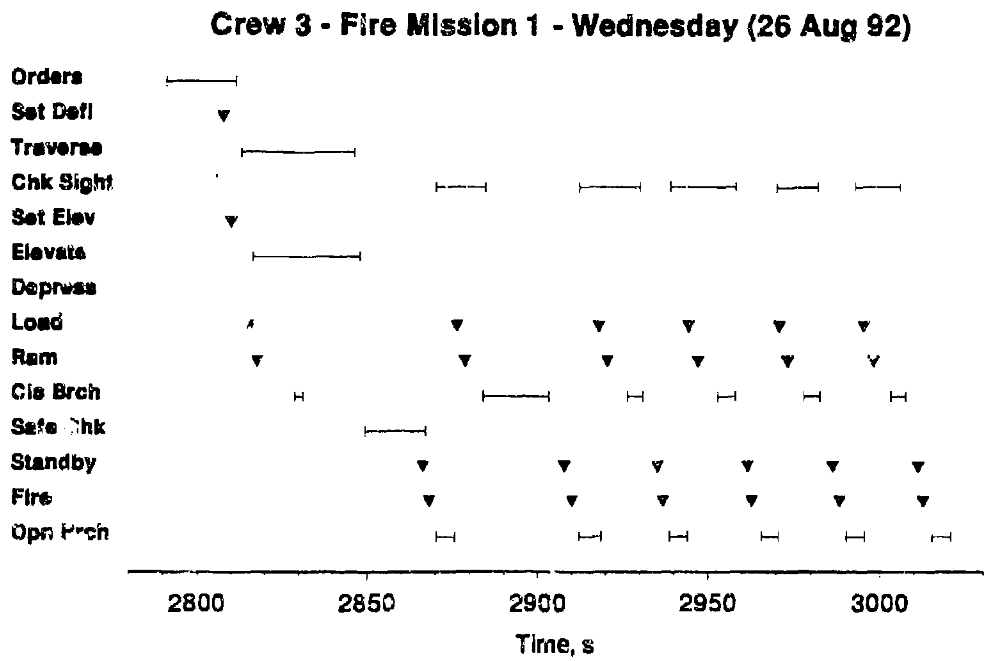


Figure A-29. Crew 3 timelines for fire missions 7 and 8 in MOPP4-S.



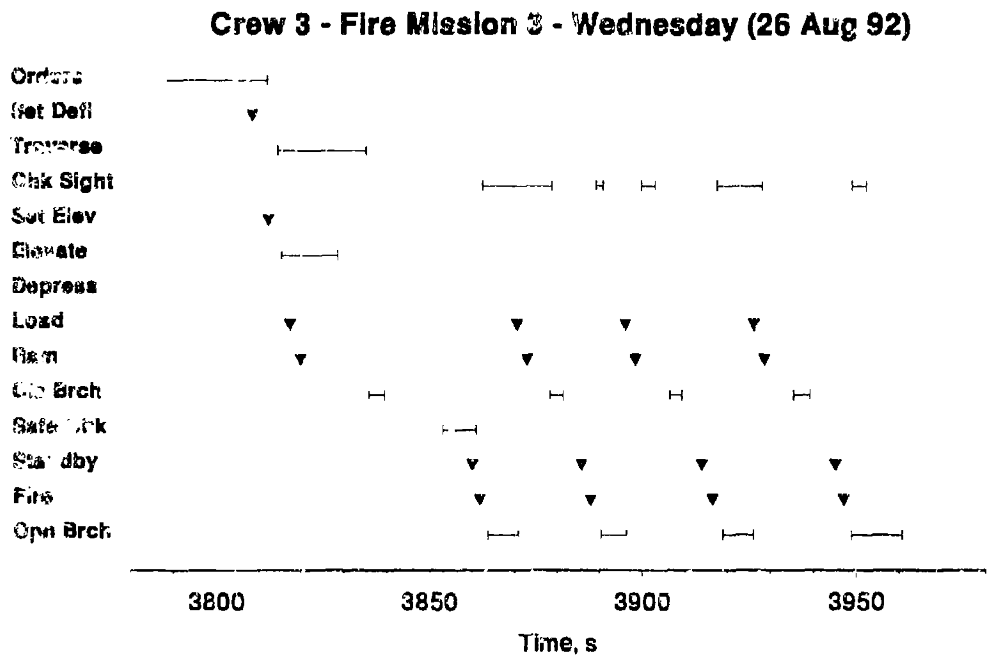


Figure A-30. Crew 3 timelines for fire missions 1 and 3 in BDU.

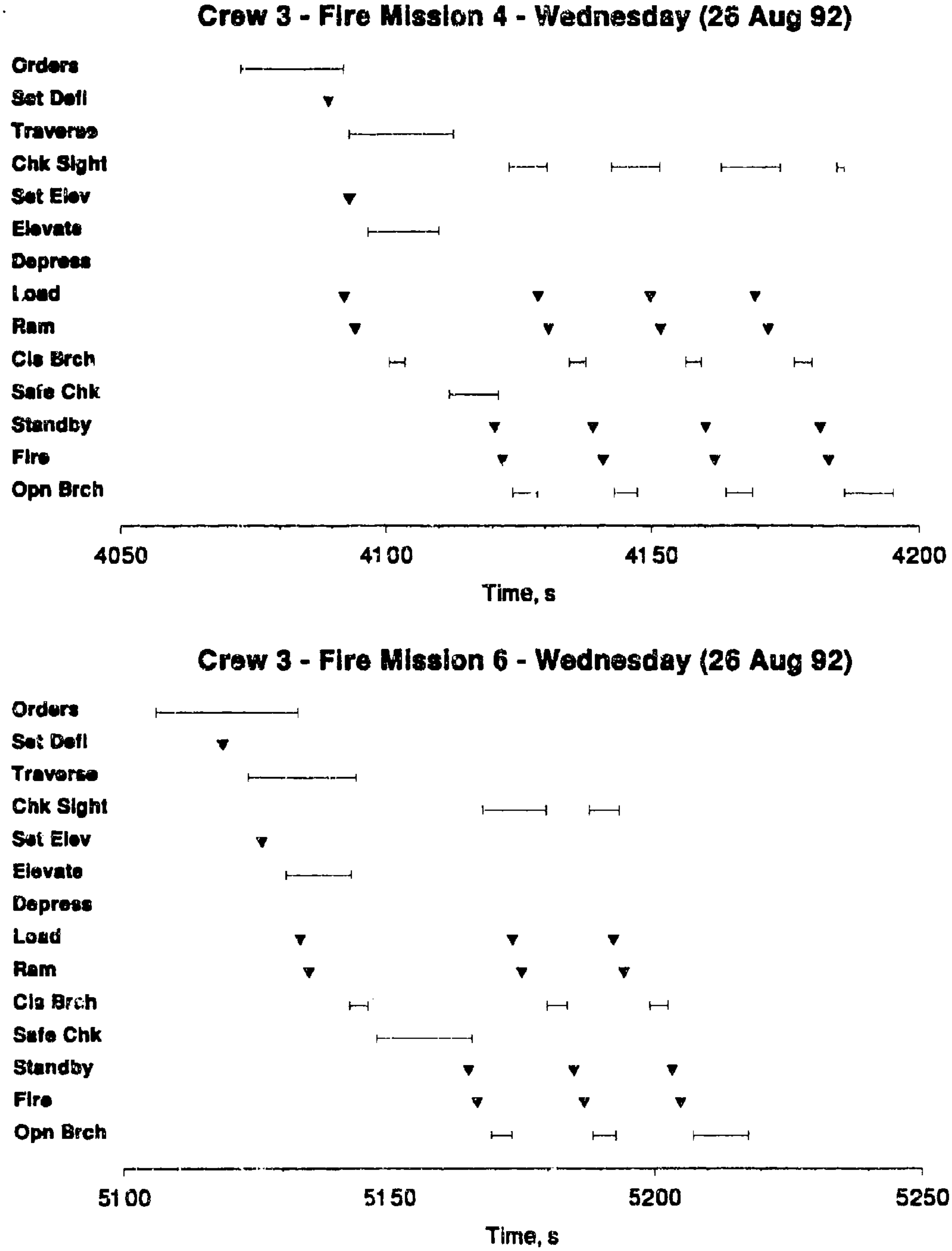
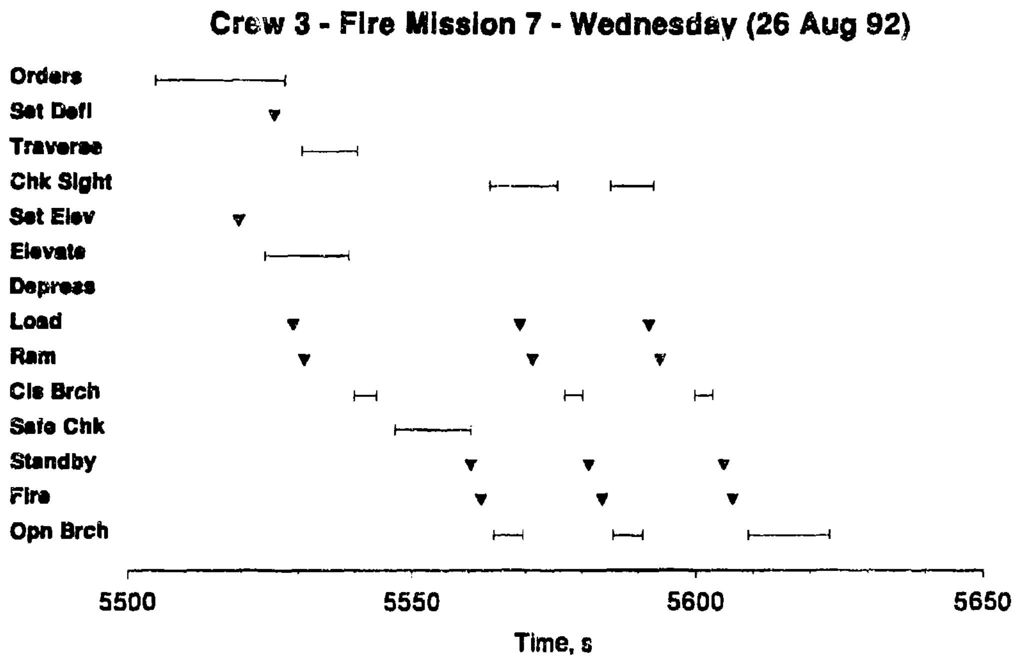


Figure A-31. Crew 3 timelines for fire missions 4 and 6 in BDU.



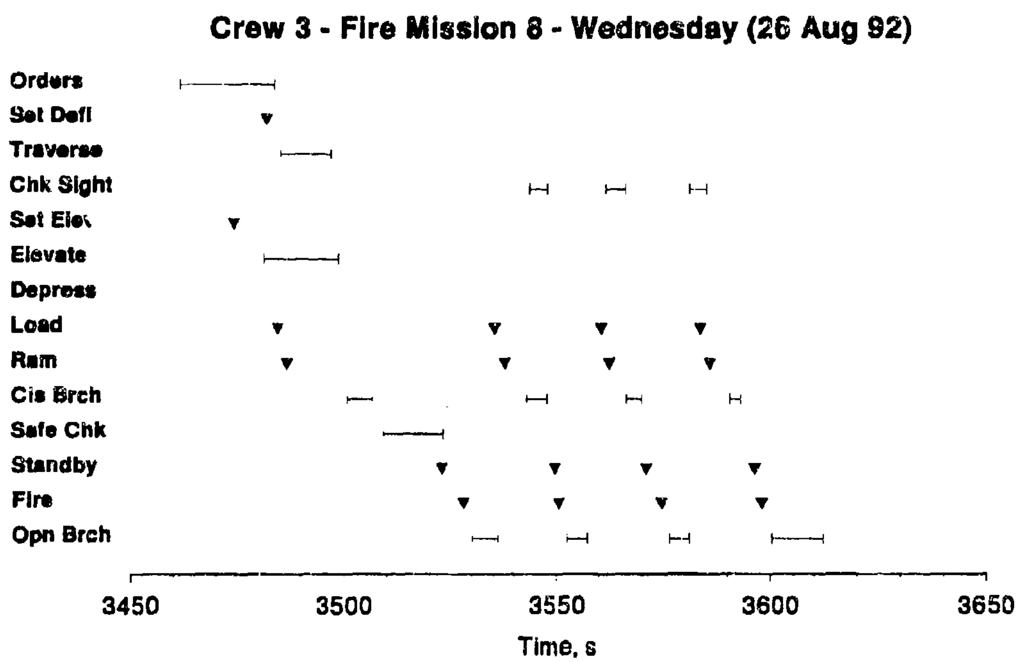
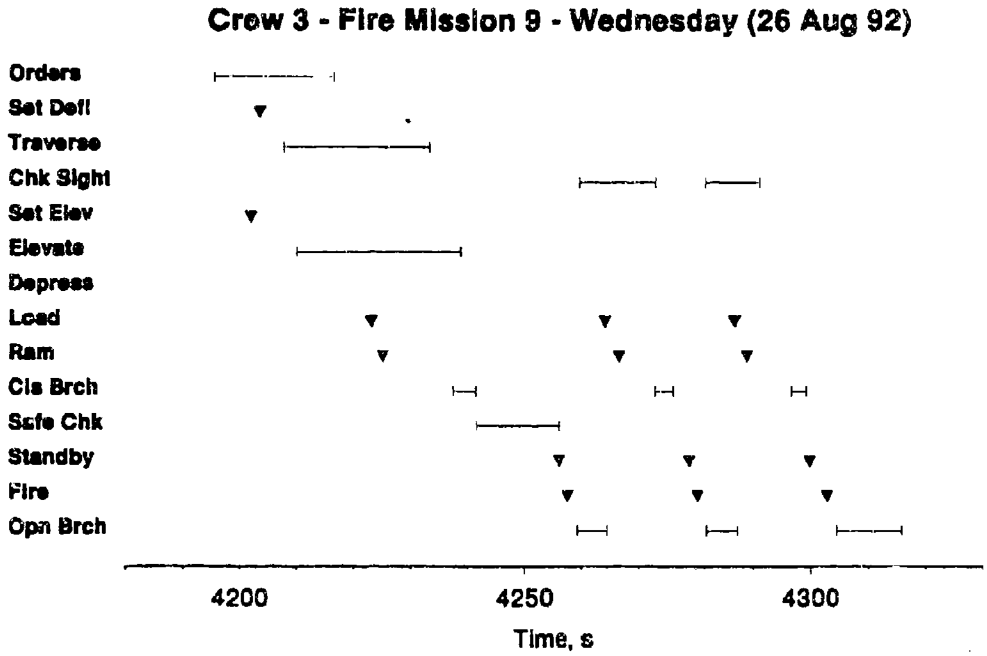


Figure A-32. Crew 3 timelines for fire missions 7 and 8 for BDU.



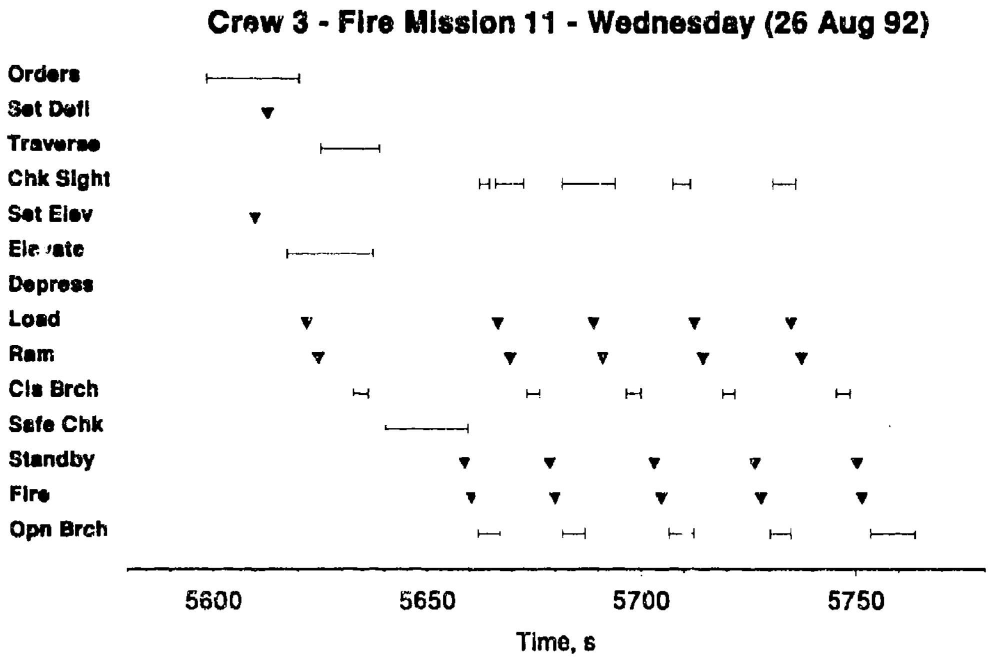
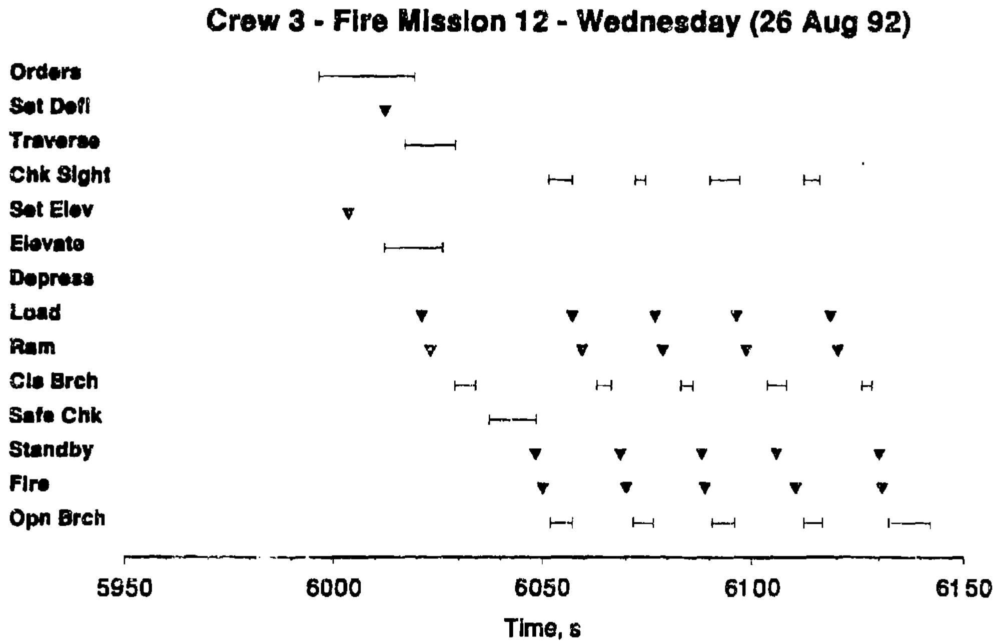


Figure A-33. Crew 3 timelines for fire missions 9 and 11 in BDU.



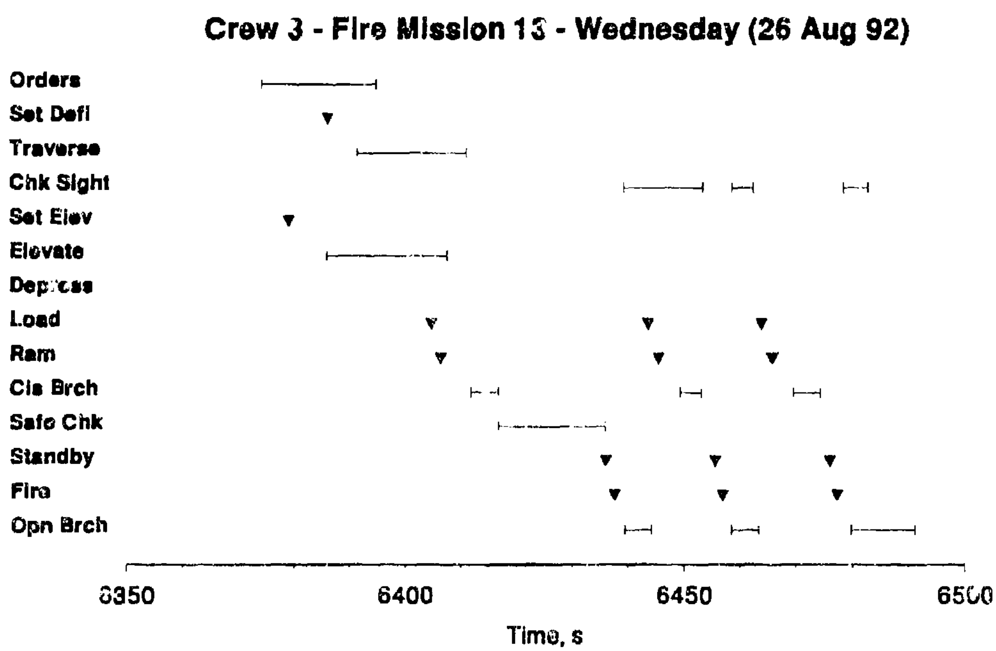
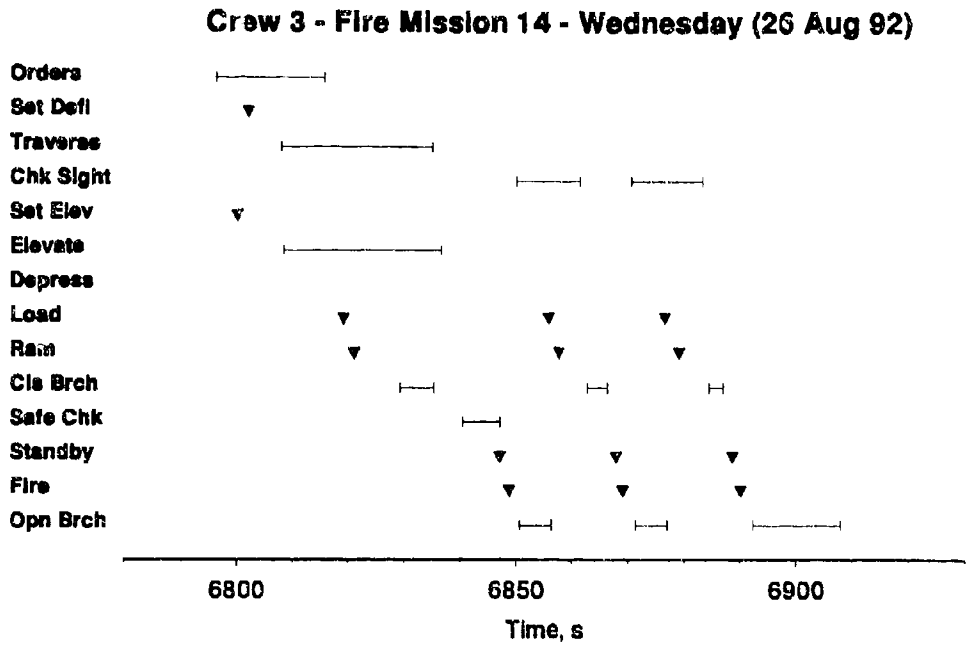


Figure A-34. Crew 3 timelines for fire missions 12 and 13 in BDU>



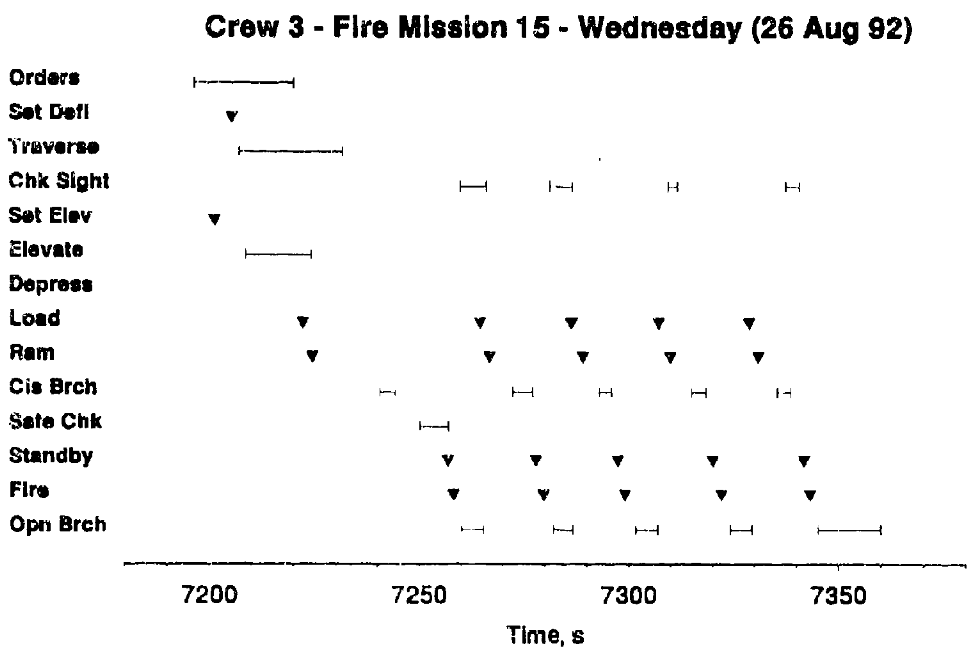
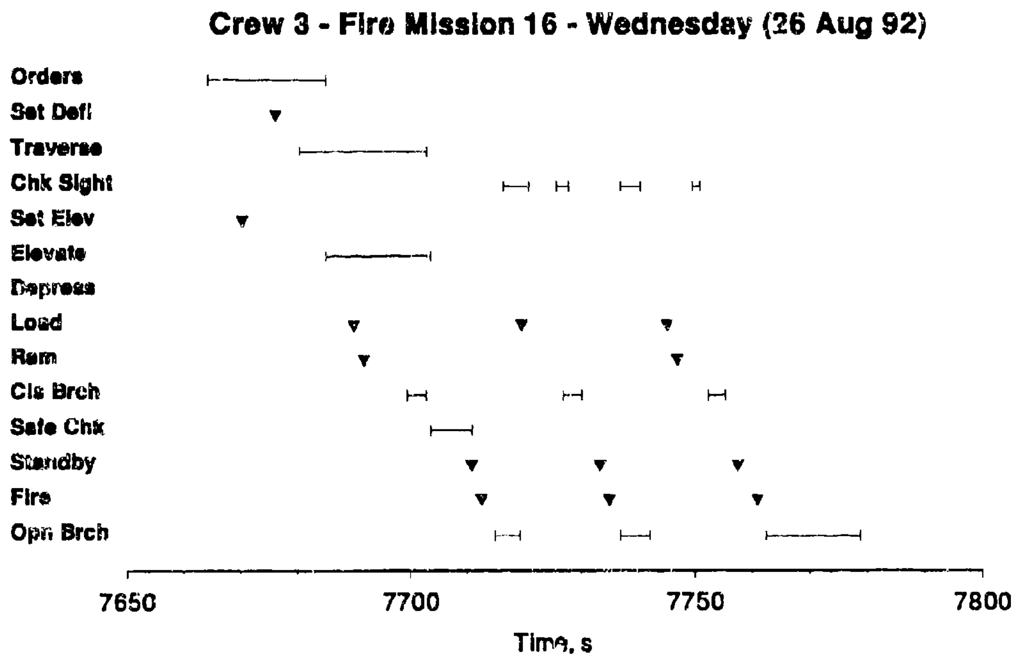


Figure A-35. Crew 3 timelines for fire missions 14 and 15 in BDU.



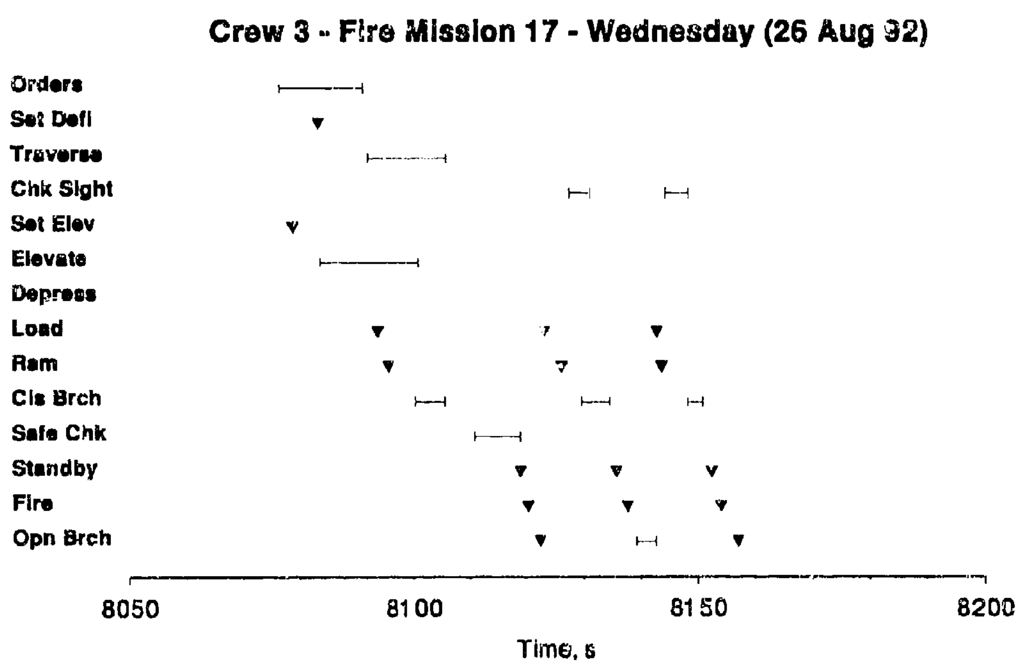
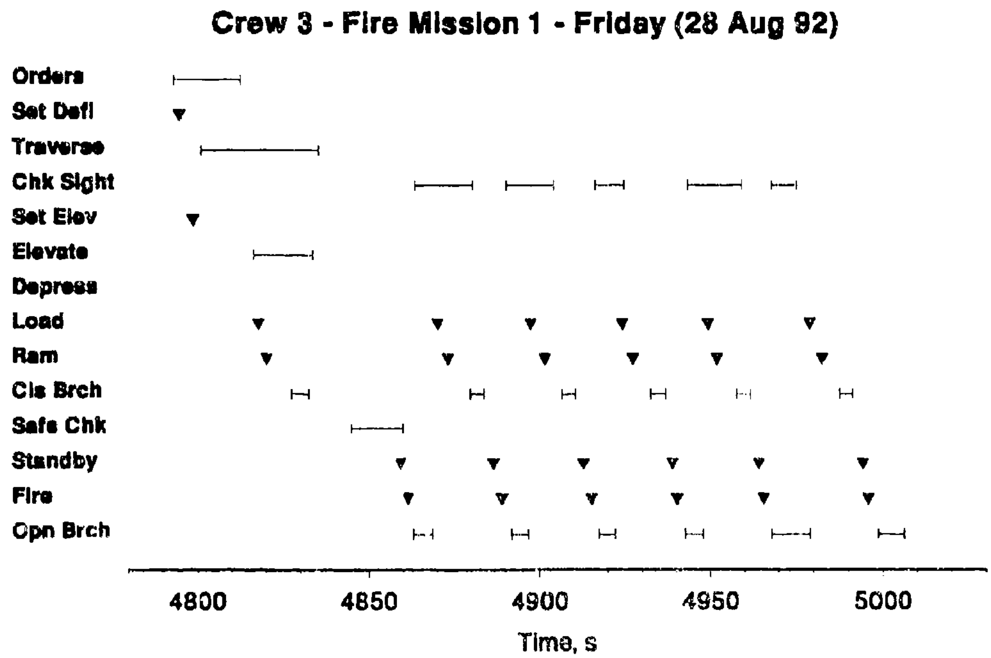


Figure A-36. Crew 3 timelines for fire missions 16 and 17 in BDU.



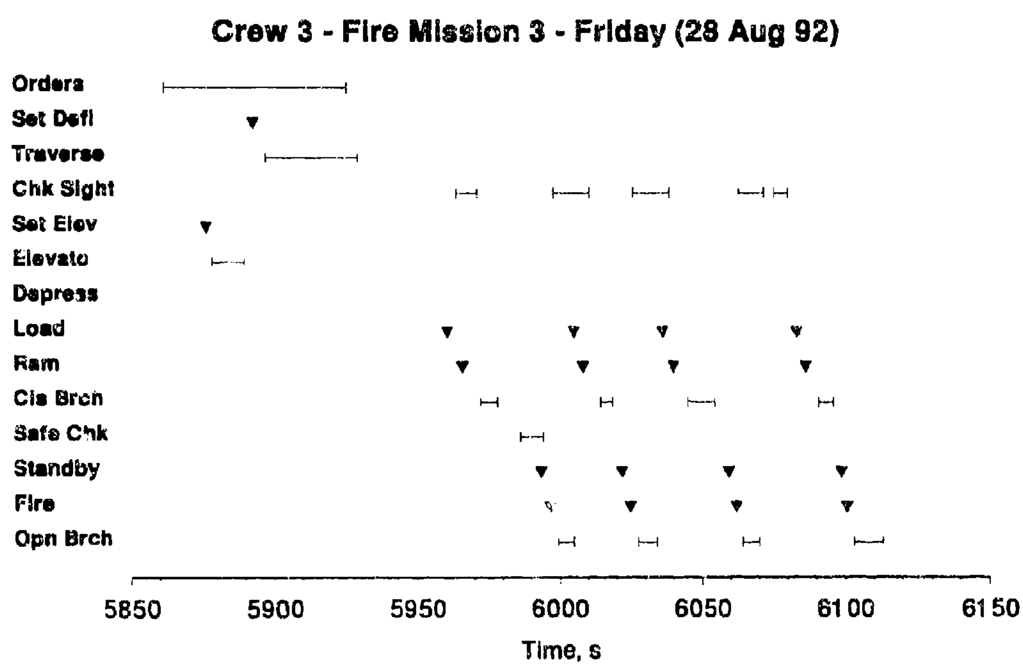
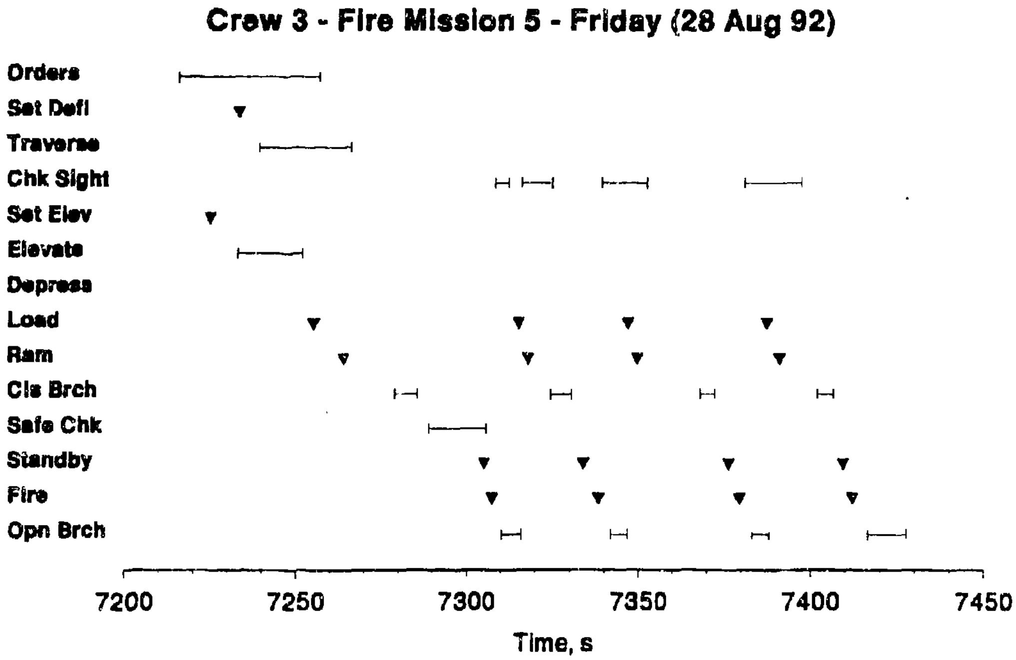


Figure A-37. Crew 3 timelines for fire missions 1 and 3 in MOPP4-R.



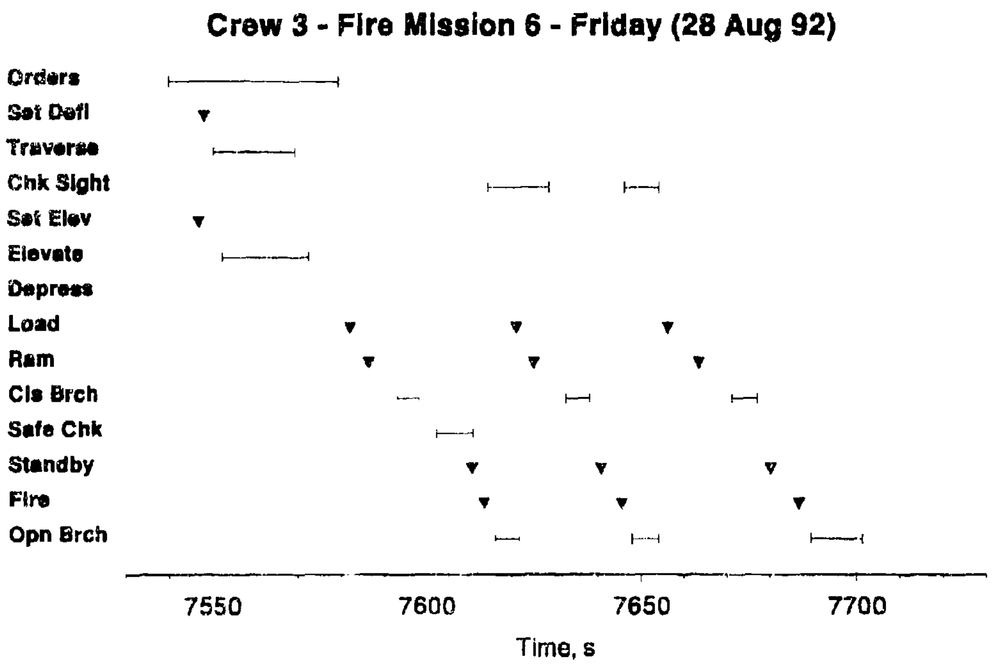
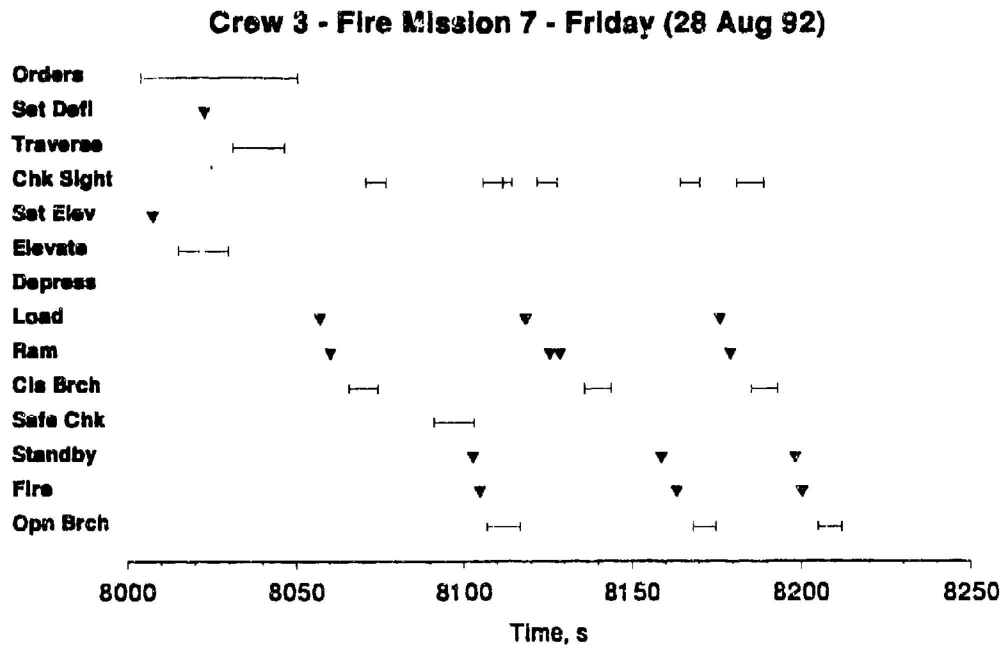


Figure A-38. Crew 3 timelines for fire missions 5 and 6 in MOPP4-R.



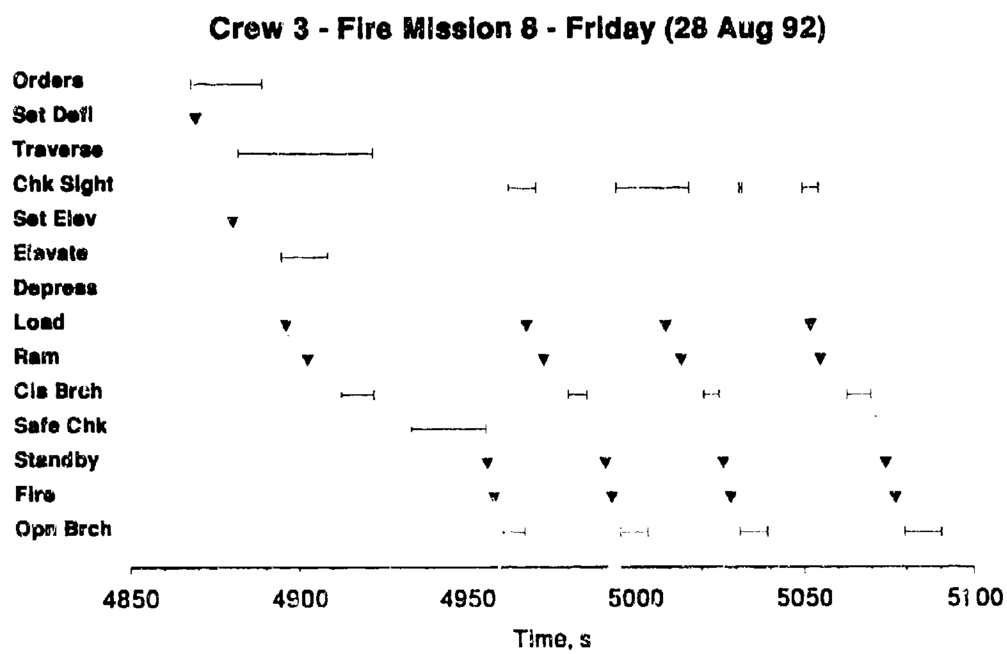


Figure A-39. Crew 3 timelines for fire missions 7 and 8 in MOPP4-R.

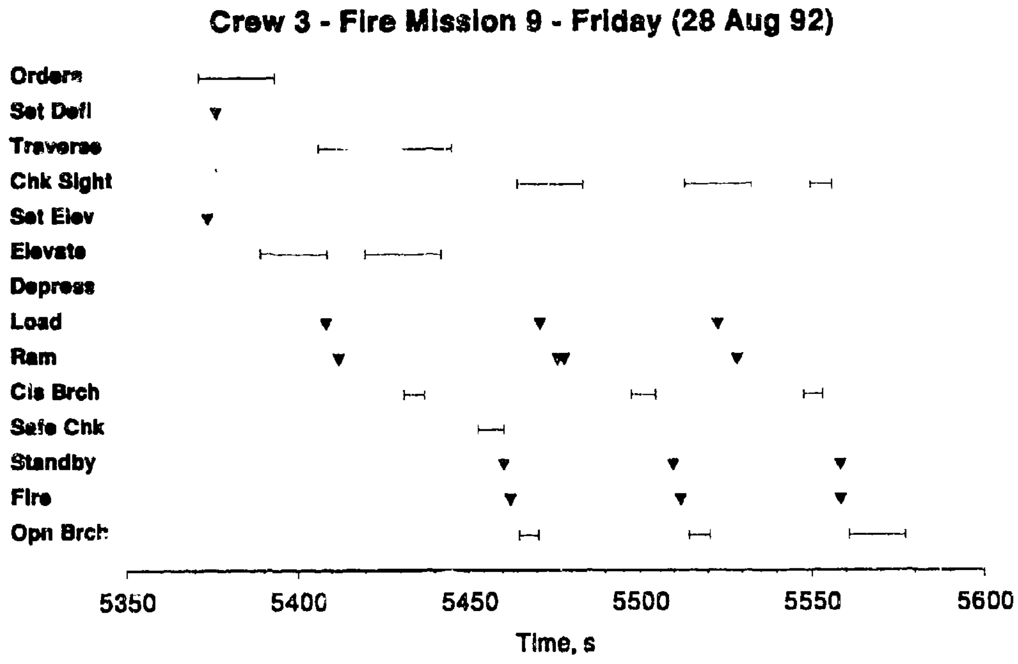


Figure A-40. Crew 3 timelines for fire mission 9 in MOPP4-R.

APPENDIX B
COMMENTS RECORDED BY DATA LOGGERS

This appendix contains a compilation of handwritten notes taken by all data loggers during each day of the exercise. Comments are unedited and are listed by fire mission (FM) with occasional comments before or between fire missions. Self reporting of mistakes made by data loggers were utilized in the reconciliation and reduction of data but are not included here. The comments listed here concern procedural variations, mistakes, or situations encountered by crew members that may influence task performance times. Reference to these comments will sometimes explain unusual times appearing in the reduced data. Specific crewmembers are referred to by number (see Table 1-6); for example, #10 is the Chief of Section of Crew 1.

DATE: Wed 8/12/92 **POSTURE:** MOPP4-S **CREW:** 1

Troops arrive about 1000 hrs.
A lot of waiting on geodetics (safety people).
Sit in shade to answer questionnaires.
Finish questionnaire (most of them) stay in shade.
Crew called out of shade (by Section Chief).

FM 1 - Projectile tray was tardy once.

FM 2 - Gunner did not check sight between every round.

FM 3 - Projectile tray late on last two rounds.
Three guys on projectile tray are slowing down.

FM 4 - Safety delay; confusion on quadrant.
Long delay loading round 1.
Delay was to re-fuze the projectile; had wrong fuze because were not expecting a high angle mission
Sight not checked often between rounds.
Elevated to initial position for loading, then elevated to firing elevation.
Gunner left position first 2 or 3 rounds. #1 filling in and checking sights.

FM 5 - Late powder 1st round. (New RTO, sounds faster.)
Gunner (?) getting powder.
Delay w/charges.

FM 6 - On the last round loader lost a few seconds because he couldn't find lanyard.

Troops visibly tired.
Sitting on trails of howitzer.
#19 suffering; checked out by the Chief of Section.

FM 7 - New charge (5) - late.

Gunner has been taking the deflection off of the Gun Display Unit (GDU).

****

DATE: Fri 8/14/92 **POSTURE:** BDU **CREW:** 1

Loader using new primer rack today for first time.

FM 1 - Standby called before loader fired with primer.

FM 2 - No comment.

FM 3 - Long elevation - started from low position.
Gunner depressing tube, Assistant Gunner elevating.

FM 4 - Powder late most shots.
Late standby, late with powder.
Safety check screwed up by safety man.
Waiting for powder man on 3rd round.
Powder often holding up firing.
Gunner depressed tube.
Difficult to tell between checking site and traverse tube..

FM 5 - Initial elevation paused for loading.
Gunner depresses tube, AG elevates.

FM 6 - Some confusion during safety check.
Section Chief called "standby" prematurely.
Standby called twice on round #1.

FM 7 - No comment.

FM 8 - Crew not ready for fire mission; rough start.
Early safety check.
Round 3 - trouble closing breech.
Standby called before loader finished with primer.
Elevation overlaps with safety check. Long time to elevate and check bubbles.
Loader trouble with the last primer.

FM 9 - No comment.

FM 10 - Once waited on ammunition.
Last round was late getting to breech.

FM 11 - No comment.

FM 12 - One late response by loader to fire command.

FM 13 - No comment.

FM 14 - No comment.

FM 15 - No comment.

FM 16 - No comment.

FM 17 - Lost lanyard on round #3. (Delay in fuzing.)

****

DATE: Mon 8/17/93 **POSTURE:** BDU **CREW:** 2

Loading primers from box, not rack.

FM 1 - 3 misfires; last had most delay, pulled lanyard three times.
Hang fire on last round (6th).

FM 2 - Hang fire (misfire) again (delay fire).
Fire command may be off - firing is lagging behind lanyard.
Elevated tube twice.
Depressed tube twice on round.

FM 3 - A couple of misfires.
3 of 5 rounds delay in firing.

FM 4 - Delay continuing in firing.
Lanyard not being pulled correctly.
Elevate tube twice for high angle.
Depress tube twice on Round 3.

FM 5 - No comment.

Note: Gunner does not significantly move.

FM 6 - Misfires are still a problem.
3rd round - delay of several seconds from misfires.
Standby to fire should show effect.

FM 7 - No comment.

FM 8 - Misfire on the first round; replace powder and primer.

FM 9 - No comment.

FM 10 - Powder delay on round 1. Dropped powder in water puddle.

FM 11 - Double elevation of tube for 1st round.

FM 12 - No comment.

FM 13 - No comment.

FM 14 - No comment.

FM 15 - Late powder round #1.

FM 16 - No comment.

****

DATE: Wed 8/19/92 **POSTURE:** MOPP4-S **CREW:** 2

FM 1 - Projectile was late on round 1.
Different gunner than Monday.

FM 2 - Trouble getting projectile on last round.

FM 3 - Powder slow 1st round.
Elevates twice for 1st round of high angle mission.
Check fire before 1st round: Approx. 10 min.
Depressed tube twice for 2nd round.
Range called check (hold) fire 10 min.; removed powder from breech, no primer. Medivac flight across range.

FM 4 - 7 man crew. Loader going after powder each time.
A lot of delay for second bag.

FM 5 - Loader still going for powder.
Crew chief (#20) is helping with both powder and tray.
Elevated twice for 1st round.

FM 6 - Mission came in while crew still on way to gun from taking questionnaire.
Loader still going for powder, not on tray.

****

DATE: Fri 8/21/92 **POSTURE:** MOPP4-R **CREW:** 2

Loader using primer rack. First time for this crew.

FM 1 - 1st round elevated twice for high angle.
2nd round - some sort of hold up.

Several drinking water.

FM 2 - 3rd round was not rammed properly.
Slow powder, fiddling with breech.
Trouble opening breech 1st time or 2nd.
Trouble with the breech, also, needed second ram probably third round.
Trouble with the breech the 2nd time.

FM 3 - No comment.

FM 4 - 1st round elevated twice for high angle.
Difficulty seating primer 1st round.
Rammers have mislaid ram twice so far, today.
Tray does not start moving until end of depression, unlike first crew who moved right up.

FM 5 - No comment.

FM 6 - Could not get breech open the first time. (new loader - #24)

FM 7 - Loader is #25 this time.
Long J (close and prime) corresponds to uncertainty on part of loader about whether primer latch was seated OK. Actually was OK in normal time.

FM 8 - Disorganized at start. Gunner is #26.

FM 9 - Voice FDC - instrument down, delay due to Sgt Thompson about 10 sec.

Delay to check instrumentation. Back on!

FM 10 - Needed 2 rams to seat one round (4th).

FM 11 - 1st round elevation screwed up - 395 corrected to 396.
Unsure loader regarding close and prime.
Ran out of primers - had to get the last one out of box.

FM 12 - Delay to get helmets just before standby 1st round.
Gunner doing AG job; AG is ammo humper.

FM 13 - Firing times lengthen out - time taken getting the powder bag into breech.

FM 14 - No comment.

Crew members now prone on backs in shade between missions.

FM 15 - 1st powder charge late.
Still very slow loading powder.

Verbal commands among cannoneers are fading, going to "autopilot".

FM 16 - No comment.

FM 17 - No comment.

****

DATE: Mon 8/24/92 **POSTURE:** MOPP4-S **CREW:** 3

No primer rack.

FM 1 - #2 round fell out of breech, needed second ram.
Assistant Gunner not using GDU to get QE, waiting for verbal command.

FM 2 - Loader is #36.
Was a delay after "fire mission" before orders called out -- unknown origin.

FM 3 - Sgt Thompson called away for phone call.
Crew delayed momentarily, then resumed action before he returned.

FM 4 - Sloppy start to mission, no apparent reason.
2nd round had loose powder wrapping.
3rd round -- instructing powder man on wrapping.
Dropped primer on 3rd.

FM 5 - No comment.

FM 6 - Loader is now #38. Opening new box of primers.
Trouble with primer latch on 1st round.
The loader fiddling around, couldn't tell if finished priming for 2nd round.
#36 was ammo humper this time.

FM 7 - No comment.

FM 8 - Loader is #38. Unwrapping primers individually during *close breech/prime*.
No Assistant Gunner - QE being done by Gunner.

FM 9 - Slow ram was real.

****

DATE: Wed 8/26/92 **POSTURE:** BDU **CREW:** 3

No primer rack.

FM 1 - Long *close breech/prime* interval was trouble seating primer

FM 2 - #36 is Loader.

FM 3 - No comment.

Sgt. Thompson motivating this crew.

FM 4 - Good data; fast mission.

FM 5 - No comment.

FM 6 - No comment.

FM 7 - No comment.

FM 8 - #36 is Loader.

Check fire; boat down range, crew standing in hot sun.

FM 9 - Projectile crew sharp.
Powder is lagging.

FM 10 - Bad primer - safety check.

FM 11 - No comment.

FM 12 - No comment.

Powder tent collapses.

FM 13 - No comment.

Fixing powder tent.

FM 14 - No comment.

FM 15 - Powder slow 1st time.

FM 16 - No comment.

FM 17 - Did not swab bore after last round. Crew was rushing to a fault.

****

DATE: Fri 8/28/92 **POSTURE:** MOPP4-R **CREW:** 3

Use primer rack today.
Instrumentation (orders) problem.

FM 1 - #36 is Loader.

FM 2 - Loaders holding back until gun depressed.

FM 3 - #39 is Loader; mission had ragged start, crew members bickering.

FM 4 - #35 is Loader. Loader had to rewrap last powder bag, then had trouble loading it because gun was already at high angle.

FM 5 - #37 is Loader.

FM 6 - #38 is Loader.

FM 7 - #33 is Loader
Cannot find lanyard once.
Double ram was real; 1st one weak.

Some rotations work better than others because of variations in performance and procedure among crew members.

FM 8 - #39 is Loader.
Ammo crew slow last round.
Breech not closed properly, causing difficulty seating primer the last time.
Gunner doing both deflection and elevation.

FM 9 - Two rams were because 1st was weak. 2nd was good.
Gunner doing both deflection and elevation.
Gunner elevated tube twice.

APPENDIX C
RESULTS OF TASK TIME ANALYSES

This appendix presents a full set of figures and tables showing the analysis of task completion times measured during the M198 howitzer fire missions. Results are presented in the order of the task definitions given in Section 4.1 with all crew postures grouped together for each task.

For each task and each crew posture, there is a set of two figures and two tables. The first figure in each set shows crew-by-crew plots of measured task completion times and the second figure shows the data aggregated across all crews. Each plot includes a regression line with a 68% confidence band. The first table in each set provides a statistical summary from the regression analyses of task times and the second table shows an analysis of variance (ANOVA) across the crews. These figures and tables follow analytical procedures and formats similar to those developed in Volume 1 for the analysis of time to first round and time between rounds. Details for this appendix, including the choice of independent variable for the various plots and regression analyses, are discussed in Section 4.2 of this volume.

Table C-0 provides a guide to the pages in this appendix that contain the figures and tables for each task with crew in each posture.

The data points plotted in the figures come from task time data files derived from reconciled event data as illustrated in Figure 3.1. Outlier data points (discussed in Section 4.2.3) are shown in the single crew plots as solid circles. These outliers are not included in regression analyses or in the ANOVA and are not included in the crew aggregate plots or in subsequent performance calculations.

The figures, regression analyses, and ANOVA are generated with the AXUM™ data analysis software.

The measured task completion times shown in the crew-by-crew plots of this Appendix are included as digital files on the 3.5" diskette that accompanies this report. Outliers are <u>included</u> in the data files. The README.TXT file includes the task time limits from Table 4-2 for separating outliers. The scenario for each task completion data point is the start time for each task within the scenario.

™AXUM is a registered trademark of TriMetrix, Inc., Seattle, Washington.

Table C-0. Location of figures and tables for each task. Note that page numbers are tabulated, not figure and table numbers.

Task	*Page numbers in this appendix*					
	BDU		*MOPP4-S*		*MOPP4-R*	
	Figures	*Tables*	*Figures*	*Tables*	*Figures*	*Tables*
Relay orders	C-3,4	C-5	C-6,7	C-8	C-9,10	C-11
Begin set deflection	C-12,13	C-14	C-15,16	C-17	C-18,19	C-20
Set deflection	C-21,22	C-23	C-24,25	C-26	C-27,28	C-29
Traverse tube	C-30,31	C-32	C-33,34	C-35	C-36,37	C-38
Begin set elevation	C-39,40	C-41	C-42,43	C-44	C-45,46	C-47
Set elevation	C-48,49	C-50	C-51,52	C-53	C-54,55	C-56
Elevate tube	C-57,58	C-59	C-60,61	C-62	C-63,64	C-65
Begin first load	C-66,67	C-68	C-69,70	C-71	C-72,73	C-74
Load projectile	C-75,76	C-77	C-78,79	C-80	C-81,82	C-83
Load first powder	C-84,85	C-86	C-87,88	C-89	C-90,91	C-92
Load first projo and pwdr	C-93,94	C-95	C-96,97	C-98	C-99,100	C-101
Lock breech and prime	C-102,103	C-104	C-105,106	C-107	C-108,109	C-110
Fire	C-111,112	C-113	C-114,115	C-116	C-117,118	C-119
Open breech	C-120,121	C-122	C-123,124	C-125	C-126,127	C-128
Swab chamber	C-129,130	C-131	C-132,133	C-134	C-135,136	C-137
Check sight	C-138,139	C-140	C-141,142	C-143	C-144,145	C-146
Begin reload	C-147,148	C-149	C-150,151	C-152	C-153,154	C-155
Reload powder	C-156,157	C-158	C-159,160	C-161	C-162,163	C-164
Reload projo and pwdr	C-165,166	C-167	C-168,169	C-170	C-171,172	C-173
Last open breech	C-174,175	C-176	C-177,178	C-179	C-180,181	C-182
Swab and inspect	C-183,184	C-185	C-186,187	C-188	C-189,190	C-191

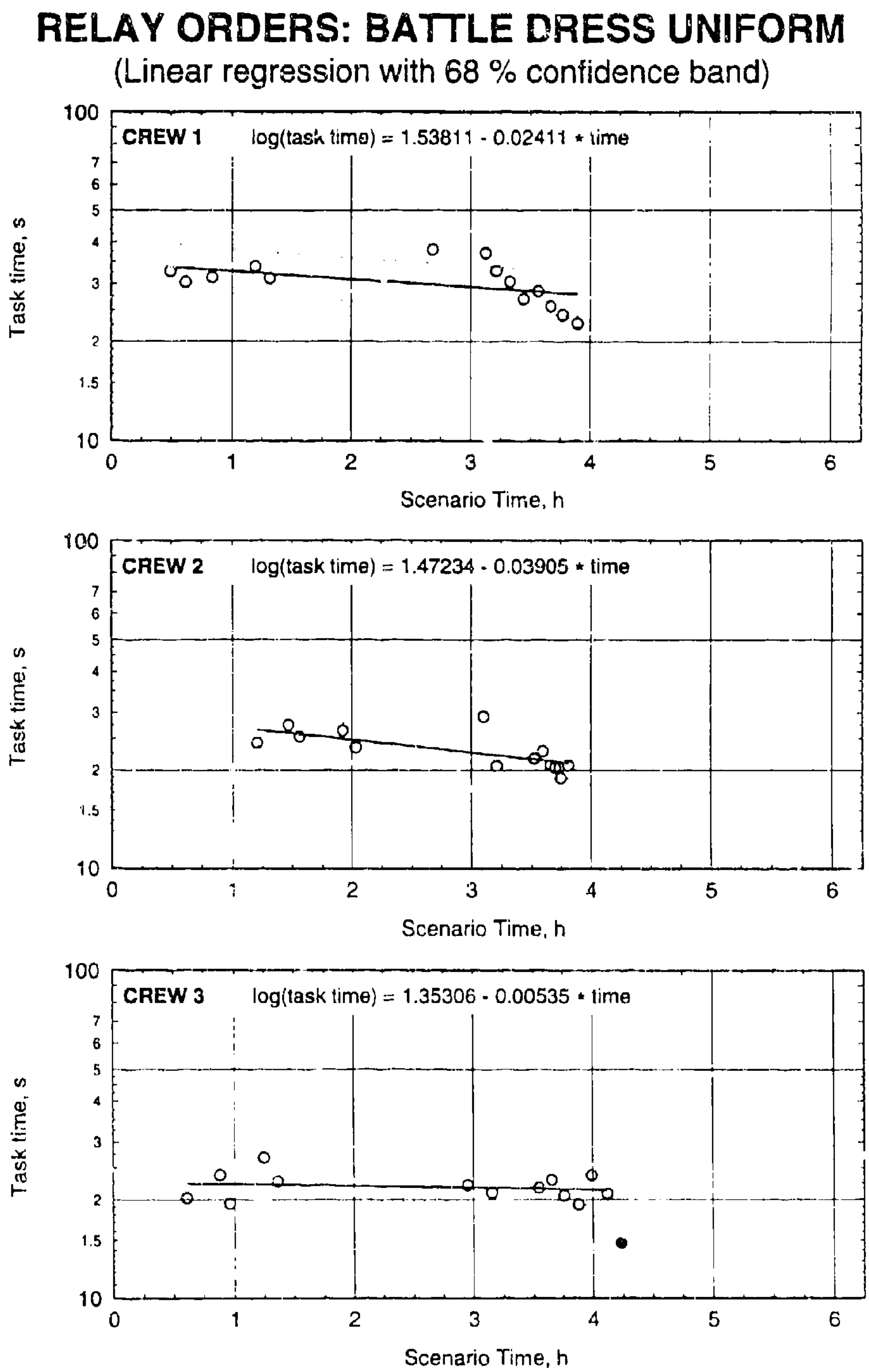


Figure C-1. Task times with regression lines for **relay orders** in BDU

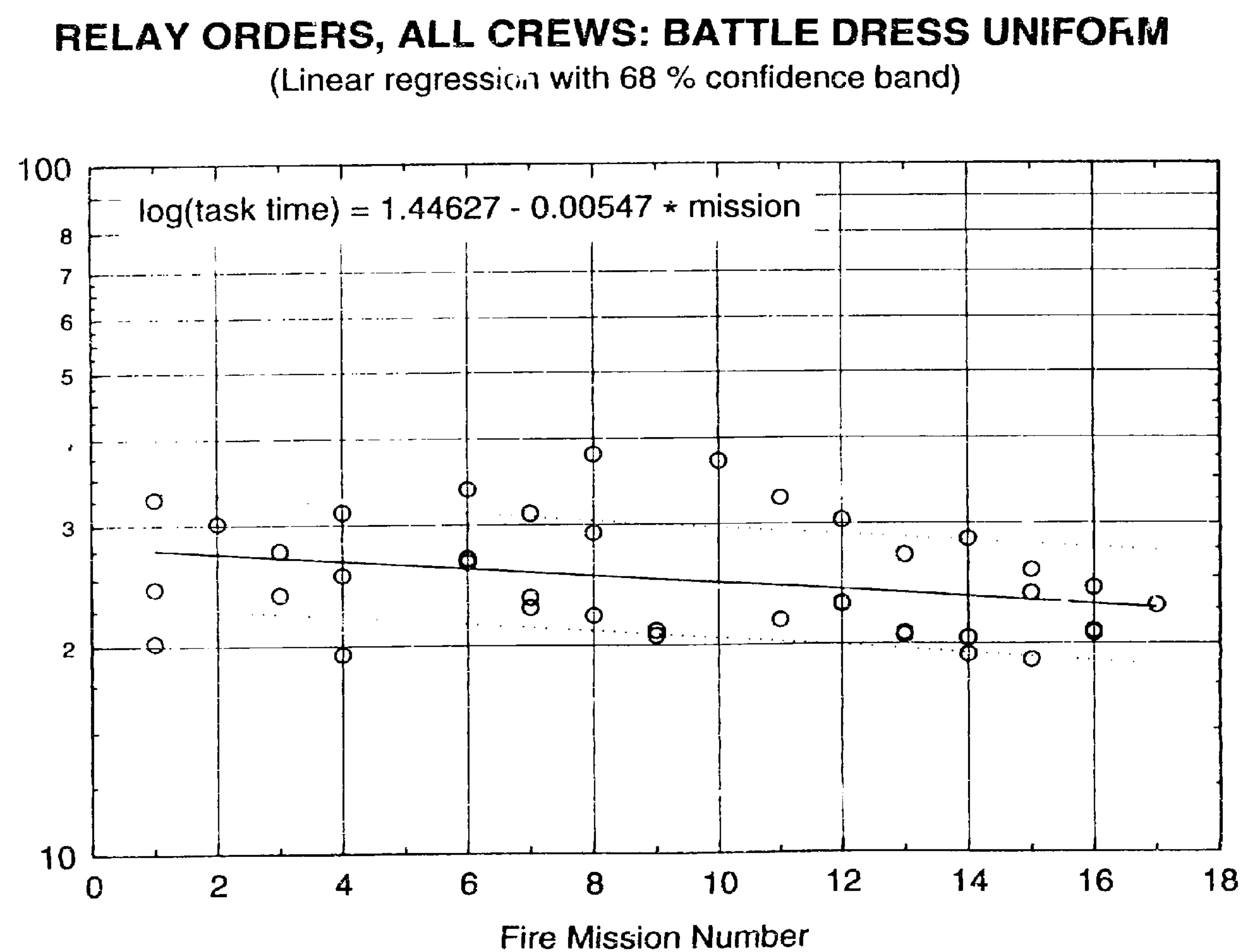


Figure C-2. Aggregate task time data with regression line for **relay orders** in BDU.

Table C-1. Statistical summary[1] for **relay orders** with crews in BDU.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	1.47757	1.36253	1.33901	1.39515
Number of Observations	14	13	13	40
Total Sum of Squares	.05594	.03942	.01926	.26452
Residual Sum of Squares	.04315	.02098	.01861	.23740
Std. Dev. of Estimate	.05997	.04368	.04114	.07904
R-squared	.22858	.46762	.03365	.10251
Adjusted R-squared	.16430	.41922	-.05419	.07889
Degrees of Freedom (df)	12	11	11	38
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	3.55577	9.66178	.38310	4.34029
Prob. Value of F	.08377	.00995	.54855	.04400
Constant	1.53811	1.47234	1.35306	1.44627
Standard error	.03588	.03735	.02541	.02754
Slope	-.02411	-.03905	-.00535	-.00547
Standard error	.01279	.01256	.00865	.00262
t-ratio	-1.88568	-3.10834	-.61895	-2.08334
prob t	.08377	.00995	.54855	.04400
Correlation Coefficient	-.47810	-.68382	-.18345	-.32017

[1]See Section 4 for discussion of regression equations and units.

Table C-2. ANOVA for **relay orders** with crews in BDU.

	Sum Sq	*DF*	*Mean Sq*
Crew	.14990	2	.11461
Error	.07495	37	.00310

Mean of Dependent Variable	1.39515
Number of Observations	40
Total Sum of Squares	.26452
Residual Sum of Squares	.11461
Std. Dev. of Estimate	.05566
R-squared	.56670
Adjusted R-squared	.54328
Degrees of Freedom (df)	37
Number of Ind Vars (K)	3
F(K-1, df)	24.19578
Prob. Value of F	.00000

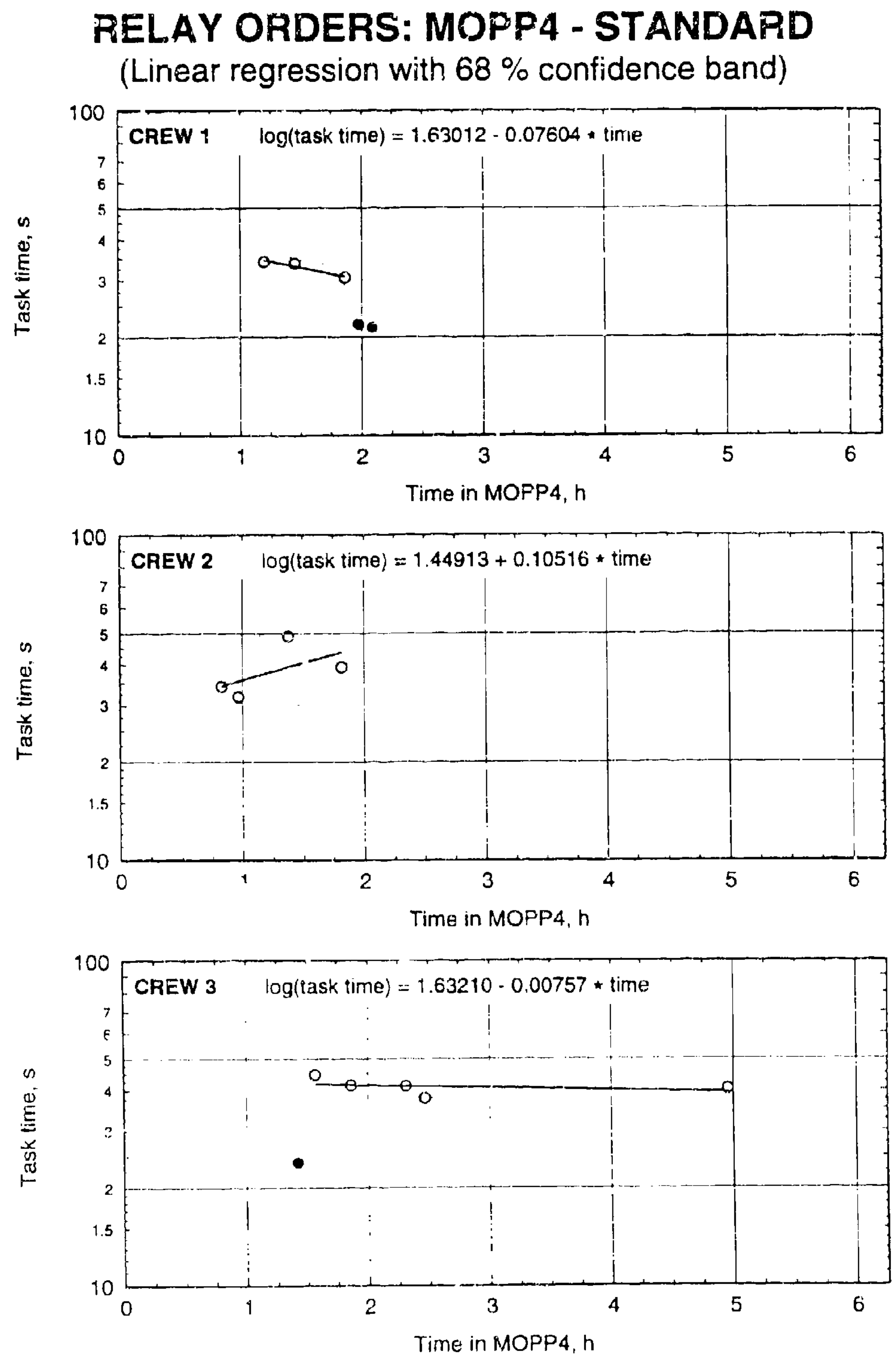


Figure C-3. Task times with regression lines for **relay orders** in MOPP4-S.

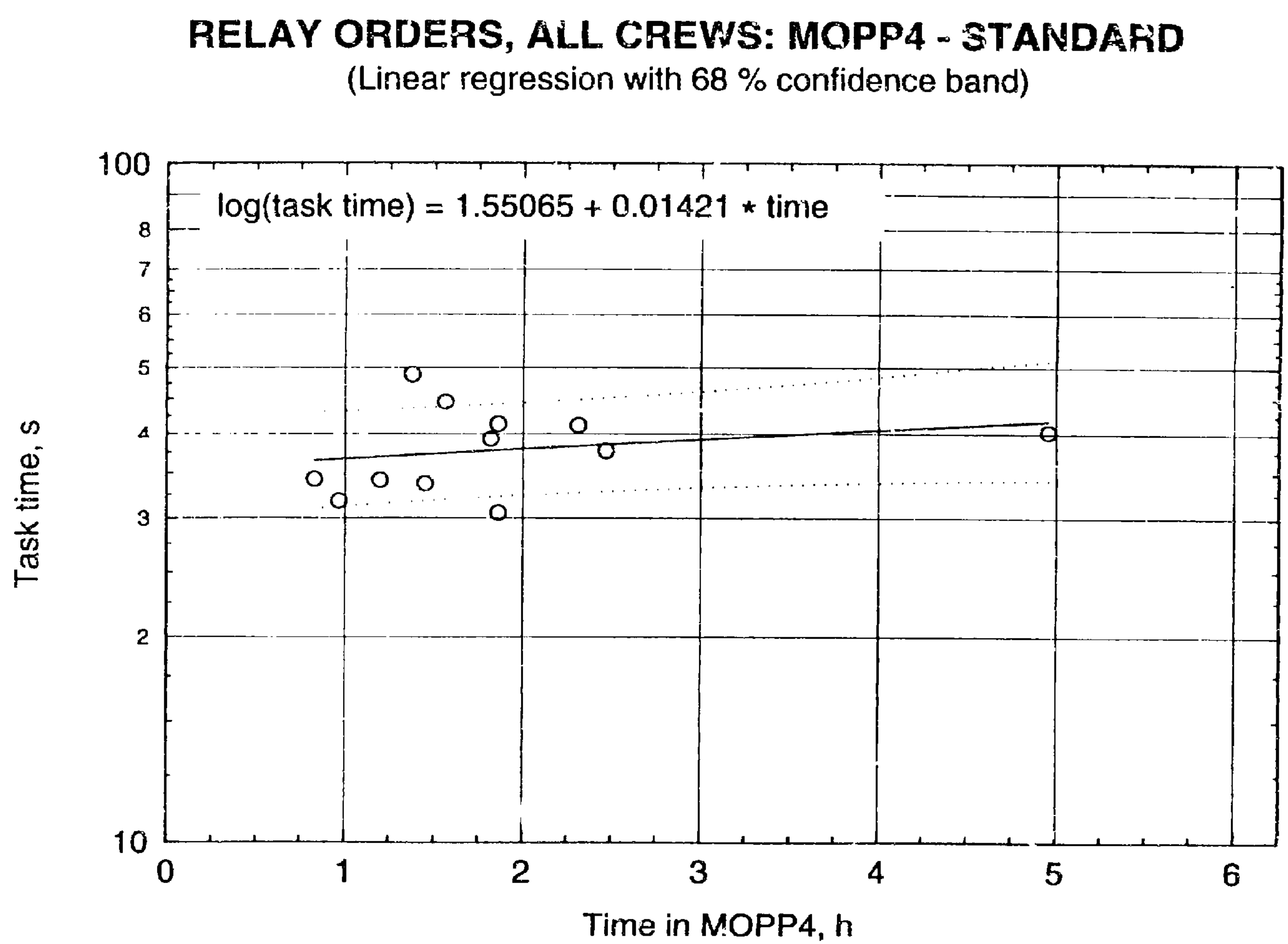


Figure C-4. Aggregate task time data with regression line for **relay orders** in MOPP4-S.

Table C-3. Statistical summary[1] for **relay orders** with crews in MOPP4-S.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	1.51586	1.58029	1.61219	1.57747
Number of Observations	3	4	5	12
Total Sum of Squares	.00143	.02012	.00267	.04166
Residual Sum of Squares	.00012	.01350	.00225	.03904
Std. Dev. of Estimate	.01101	.08216	.02739	.06249
R-squared	.91509	.32884	.15593	.06269
Adjusted R-squared	.83018	-.00674	-.12543	-.03104
Degrees of Freedom (df)	1	2	3	10
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	10.77712	.97991	.55420	.66885
Prob. Value of F	.18824	.42656	.51062	.43251
Constant	1.63012	1.44913	1.63210	1.55065
Standard error	.03538	.13872	.02941	.03743
Slope	-.07604	.10516	-.00757	.01421
Standard error	.02316	.10623	.01016	.01737
t-ratio	-3.28285	.98990	-.74445	.81783
prob t	.18824	.42656	.51062	.43251
Correlation Coefficient	-.95660	.57344	-.39488	.25038

[1]See Section 4 for discussion of regression equations and units.

Table C-4. ANOVA for **relay orders** with crews in MOPP4-S.

	Sum Sq	*DF*	*Mean Sq*
Crew	.01745	2	.02421
Error	.00872	9	.00269

Mean of Dependent Variable	1.57747
Number of Observations	12
Total Sum of Squares	.04166
Residual Sum of Squares	.02421
Std. Dev. of Estimate	.05186
R-squared	.41881
Adjusted R-squared	.28966
Degrees of Freedom (df)	9
Number of Ind Vars (K)	3
F(K-1, df)	3.24280
Prob. Value of F	.08698

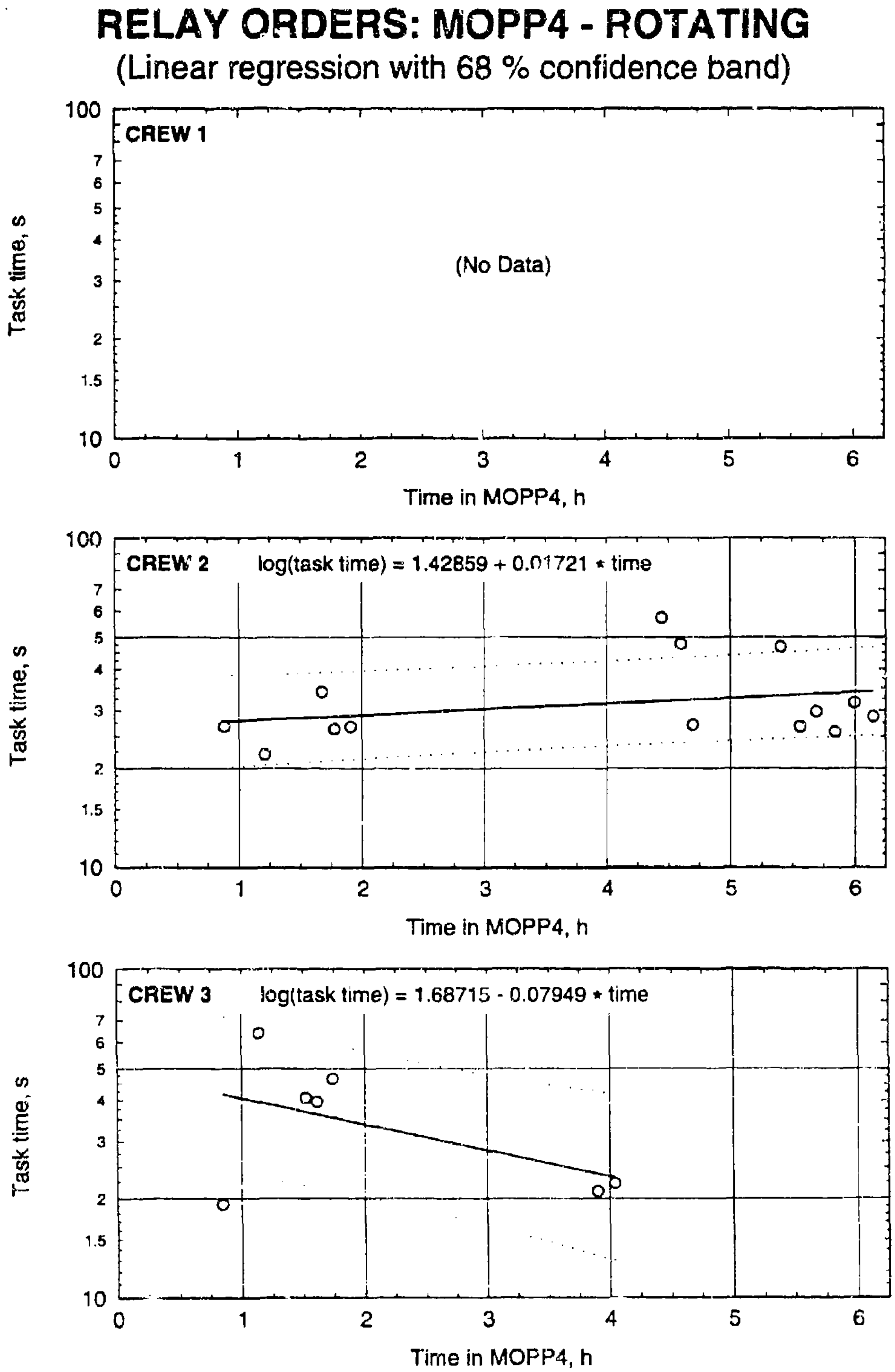


Figure C-5. Task times with regression lines for **relay orders** in MOPP4-R.

RELAY ORDERS, CREWS 2 AND 3: MOPP4 - ROTATING

(Linear regression with 68 % confidence band)

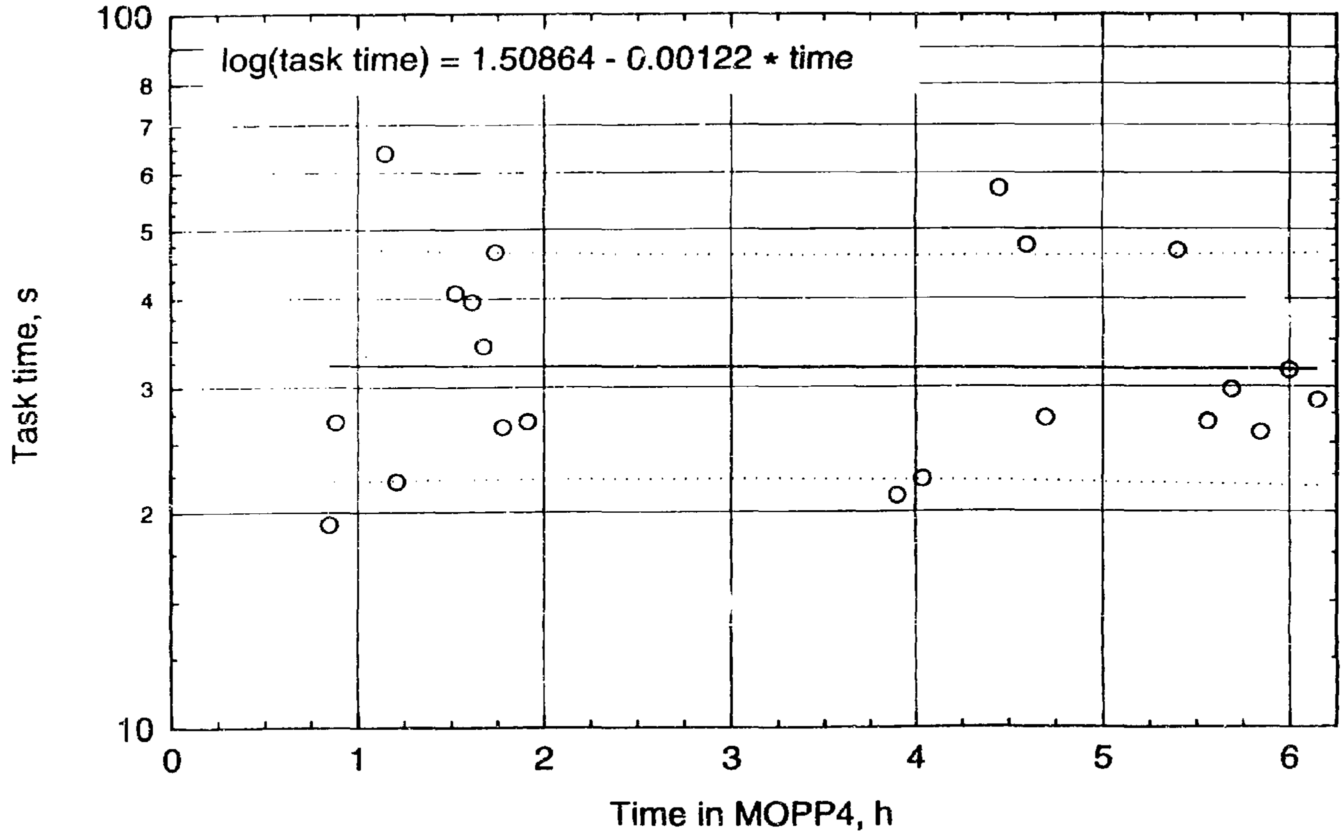


Figure C-6. Aggregate task time data with regression line for **relay orders** in MOPP4-R.

Table C-5. Statistical summary[1] for **relay orders** with crews in MOPP4-R.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	No Data	1.49725	1.51912	1.50454
Number of Observations		14	7	21
Total Sum of Squares		.18778	.24169	.43170
Residual Sum of Squares		.17221	.17735	.43159
Std. Dev. of Estimate		.11980	.18833	.15072
R-squared		.08291	.26622	.00027
Adjusted R-squared		.00648	.11947	-.05235
Degrees of Freedom (df)		12	5	19
Number of Ind Vars (K)		2	2	2
F(K-1, df)		1.08485	1.81404	.00516
Prob. Value of F		.31815	.23585	.94347
Constant		1.42859	1.68715	1.50864
Standard error		.07329	.14363	.06580
Slope		.01721	-.07949	-.00122
Standard error		.01652	.05902	.01694
t-ratio		1.04156	-1.34686	-.07185
prob t		.31815	.23585	.94347
Correlation Coefficient		.28794	-.51597	-.01648

[1]See Section 4 for discussion of regression equations and units

Table C-6. ANOVA for **relay orders** with crews in MOPP4-R.

	Sum Sq	*DF*	*Mean Sq*
Crew	.00223	1	.42947
Error	.00223	19	.02260

Mean of Dependent Variable	1.50454
Number of Observations	21
Total Sum of Squares	.43170
Residual Sum of Squares	.42947
Std. Dev. of Estimate	.15035
R-squared	.00517
Adjusted R-squared	-.04719
Degrees of Freedom (df)	19
Number of Ind Vars (K)	2
F(K-1, df)	.09871
Prob. Value of F	.75680

BEGIN SET DEFLECTION: BATTLE DRESS UNIFORM

(Linear regression with 68 % confidence band)

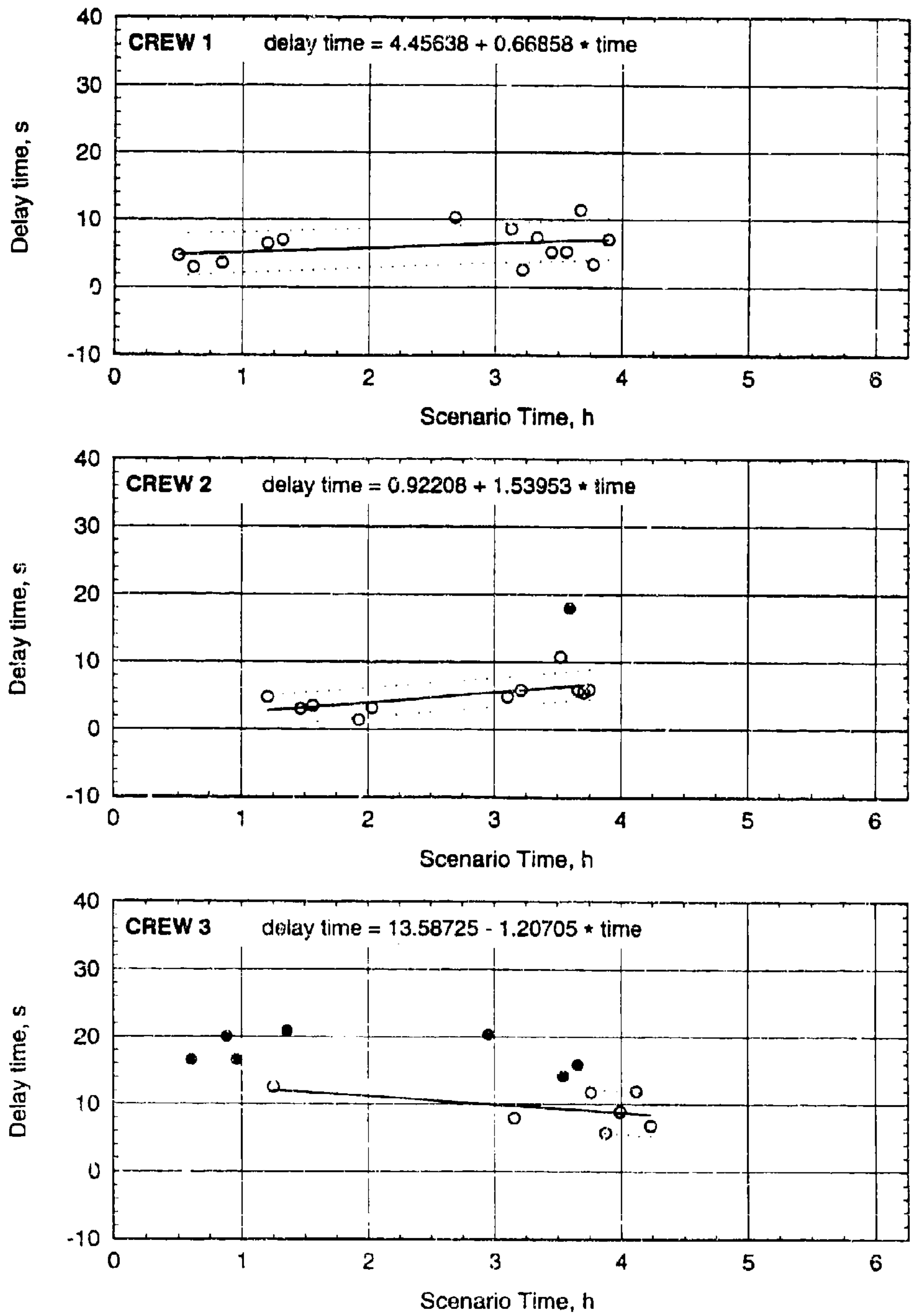


Figure C-7. Task times with regression lines for **begin set deflection** in BDU.

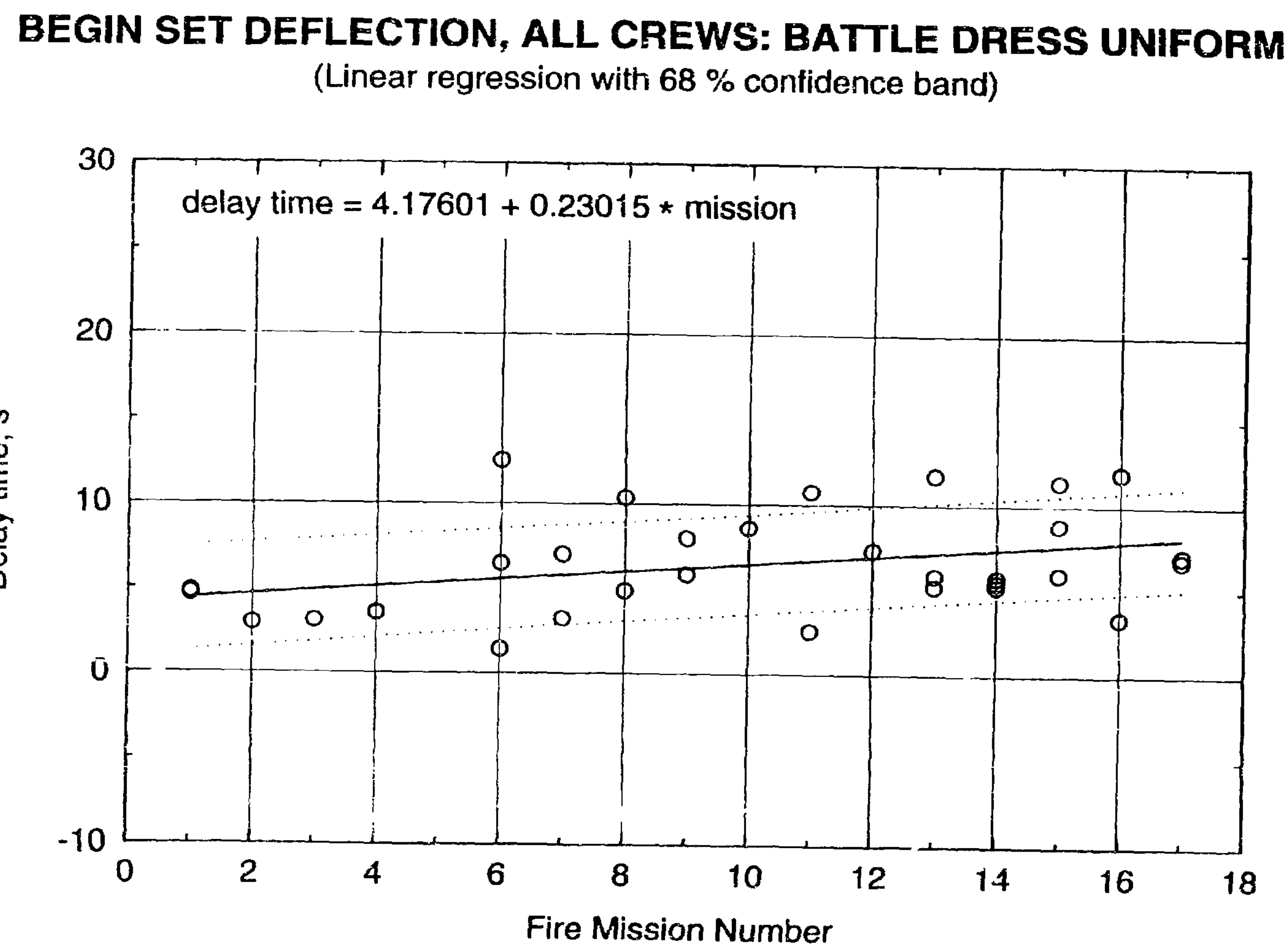


Figure C-8. Aggregate task time data with regression line for **begin set deflection** in BDU.

Table C-7. Statistical summary[1] for **begin set deflection** with crews in BDU.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	6.13500	5.00182	9.38286	6.45594
Number of Observations	14	11	7	32
Total Sum of Squares	95.84334	57.42476	44.24994	282.18710
Residual Sum of Squares	86.01369	33.27636	34.70349	242.52820
Std. Dev. of Estimate	2.67728	1.92286	2.63452	2.84329
R-squared	.10256	.42052	.21574	.14054
Adjusted R-squared	.02777	.35614	.05889	.11189
Degrees of Freedom (df)	12	9	5	30
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	1.37136	6.53123	1.37543	4.90570
Prob. Value of F	.26431	.03091	.29371	.03451
Constant	4.45638	.92208	13.58725	4.17601
Standard error	1.60209	1.69839	3.72068	1.14553
Slope	.66858	1.53953	-1.20705	.23015
Standard error	.57093	.60241	1.02922	.10391
t-ratio	1.17105	2.55563	-1.17279	2.21488
prob t	.26431	.03091	.29371	.03451
Correlation Coefficient	.32025	.64848	-.46448	.37489

[1]See Section 4 for discussion of regression equations and units.

Table C-8. ANOVA for **begin set deflection** with crews in BDU.

	Sum Sq	*DF*	*Mean Sq*
Crew	84.66911	2	197.51800
Error	42.33455	29	6.81097

Mean of Dependent Variable	6.45594
Number of Observations	32
Total Sum of Squares	282.18710
Residual Sum of Squares	197.51800
Std. Dev. of Estimate	2.60978
R-squared	.30005
Adjusted R-squared	.25177
Degrees of Freedom (df)	29
Number of Ind Vars (K)	3
F(K-1, df)	6.21564
Prob. Value of F	.00567

BEGIN SET DEFLECTION: MOPP4 - STANDARD

(Linear regression with 68 % confidence band)

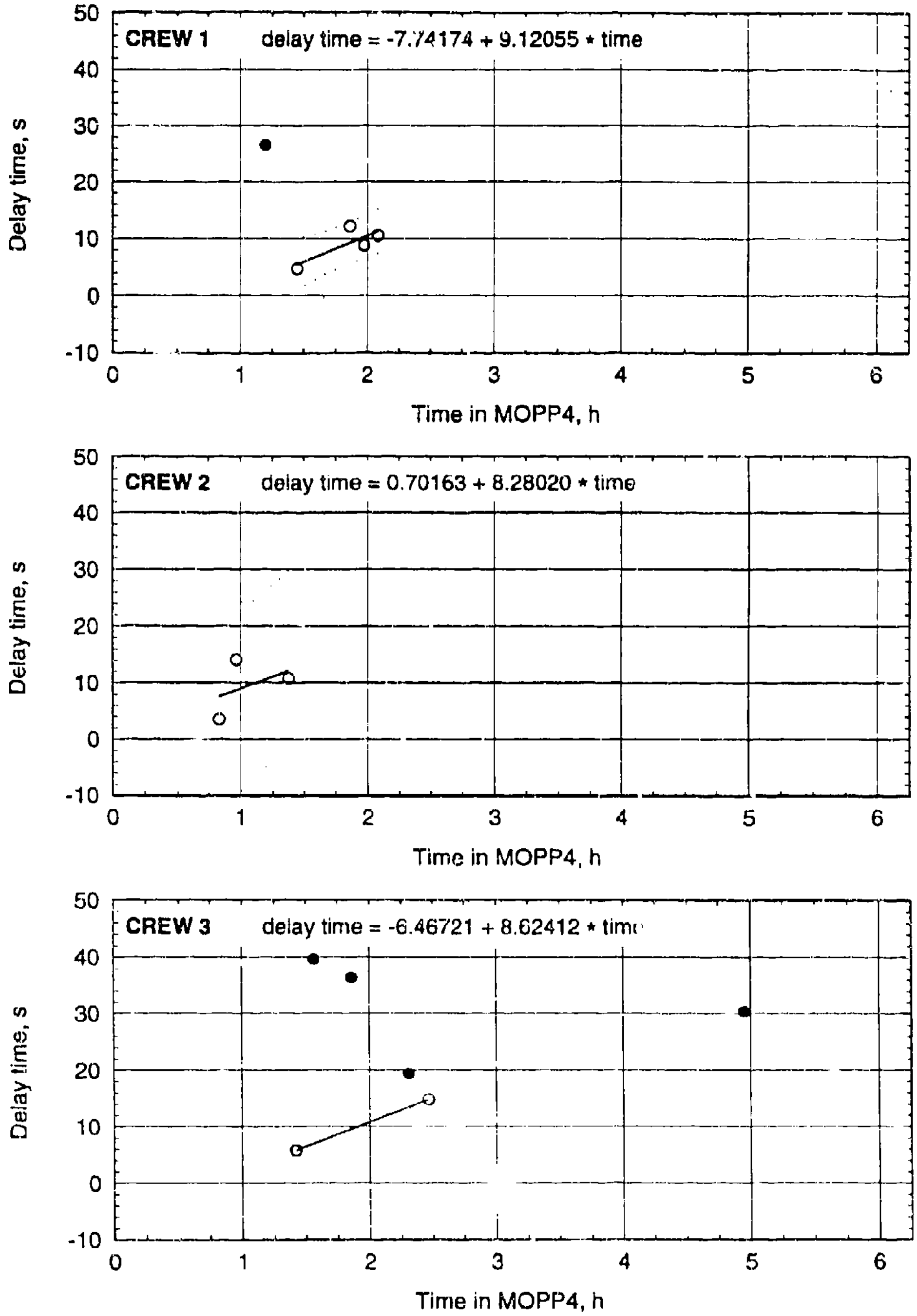


Figure C-9. Task times with regression lines for **begin set deflection** in MOPP4-S.

BEGIN SET DEFLECTION, ALL CREWS: MOPP4 - STANDARD

(Linear regression with 68 % confidence band)

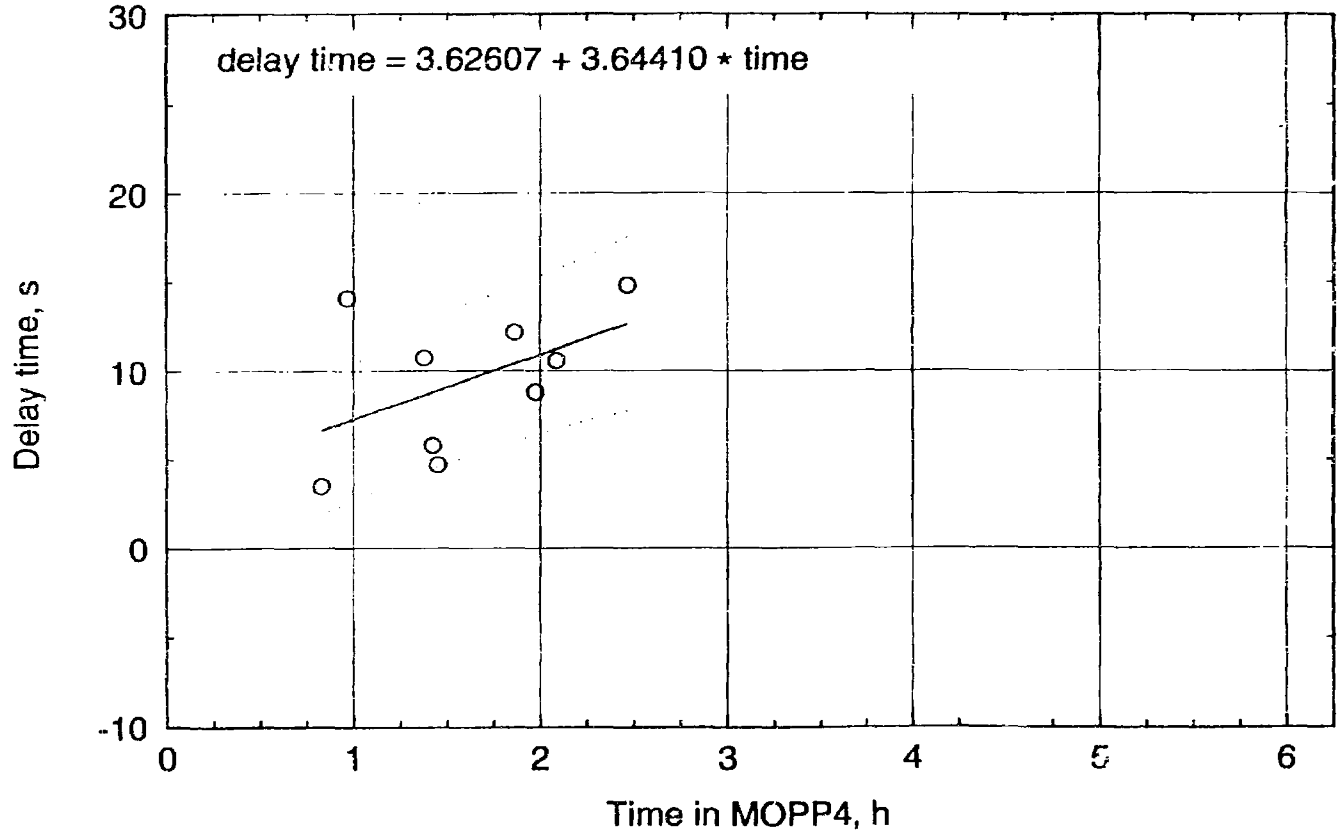


Figure C-10. Aggregate task time data with regression line for **begin set deflection** in MOPP4-S.

Table C-9. Statistical summary[1] for **begin set deflection** with crews in MOPP4-S.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	9.06250	9.45333	10.30500	9.46889
Number of Observations	4	3	2	9
Total Sum of Squares	30.87508	58.87546	40.59005	132.40010
Residual Sum of Squares	11.67998	47.66978	.00000	101.89070
Std. Dev. of Estimate	2.41661	6.90433	.00000	3.81521
R-squared	.62170	.19033	1.00000	.23043
Adjusted R-squared	.43255	-.61934	.00000	.12050
Degrees of Freedom (df)	2	1	0	7
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	3.28684	.23507		2.09603
Prob. Value of F	.21152	.71260		.19094
Constant	-7.74174	.70163	-6.46721	3.62607
Standard error	9.34736	18.48565		4.23137
Slope	9.12055	8.28020	8.62412	3.64410
Standard error	5.03074	17.07825		2.51705
t-ratio	1.81296	.48484		1.44777
prob t	.21152	.71260		.19094
Correlation Coefficient	.78848	.43627	1.00000	.48003

[1]See Section 4 for discussion of regression equations and units.

Table C-10. ANOVA for **begin set deflection** with crews in MOPP4-S.

	Sum Sq	*DF*	*Mean Sq*
Crew	2.05950	2	130.34060
Error	1.02975	6	21.72343

Mean of Dependent Variable	9.46889
Number of Observations	9
Total Sum of Squares	132.40010
Residual Sum of Squares	130.34060
Std. Dev of Estimate	4.66084
R-squared	.01556
Adjusted R-squared	-.31259
Degrees of Freedom (df)	6
Number of Ind Vars (K)	3
F(K-1, df)	.04740
Prob. Value of F	.95406

BEGIN SET DEFLECTION: MOPP4 - ROTATING

(Linear regression with 68 % confidence band)

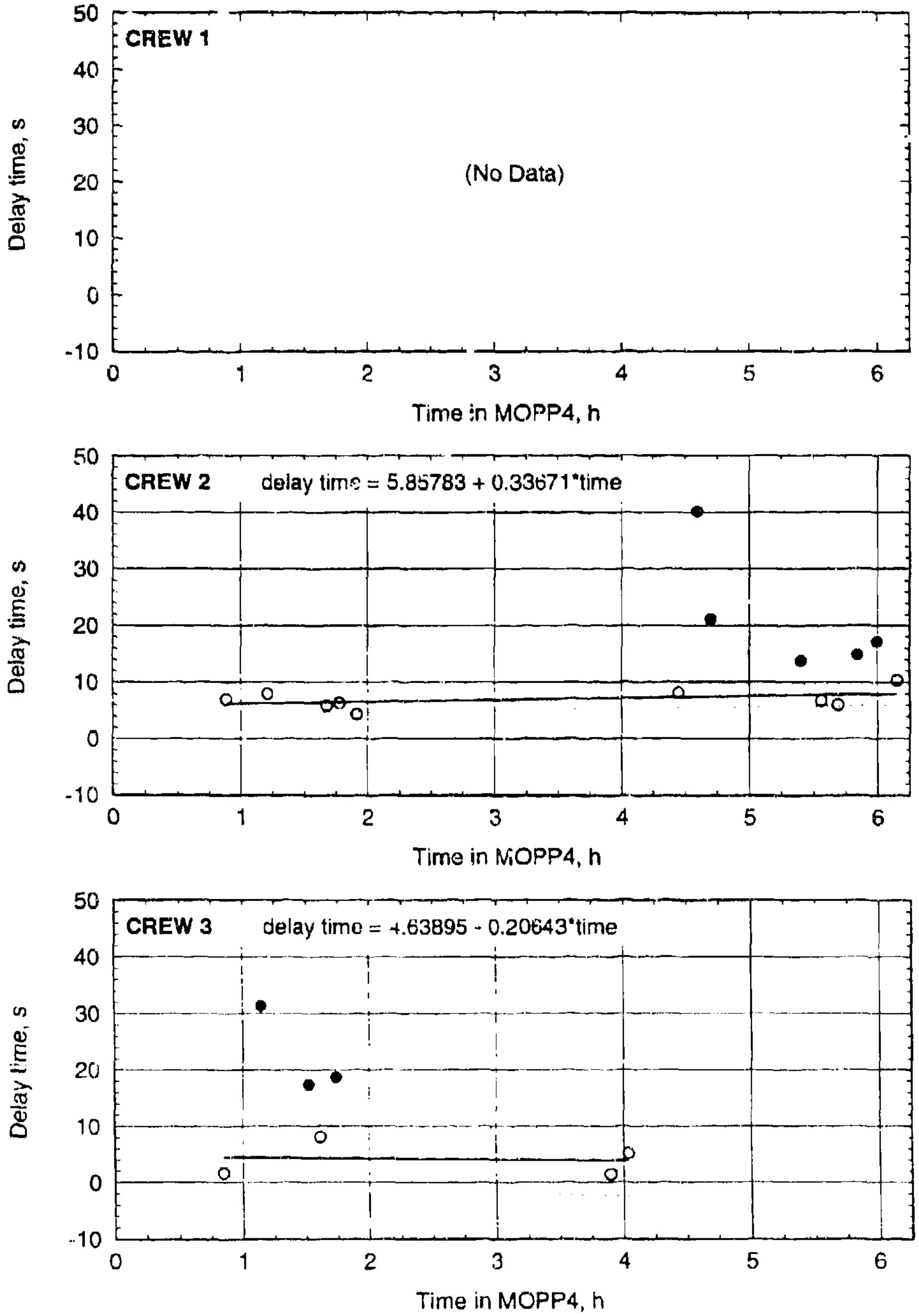


Figure C-11. Task times with regression lines for **begin set deflection** in MOPP4-R.

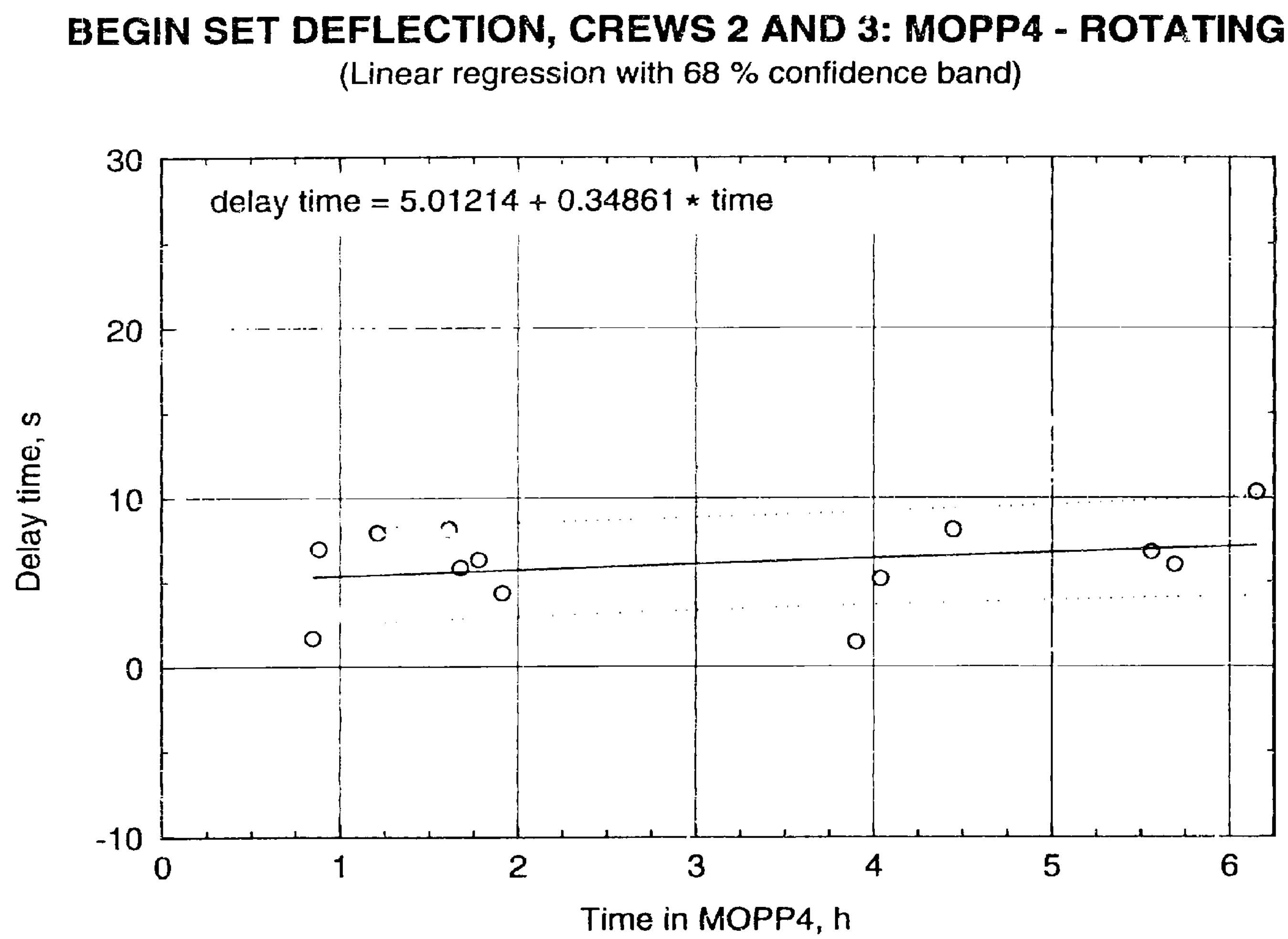


Figure C-12. Aggregate task time data with regression line for **begin set deflection** in MOPP4-R.

Table C-11. Statistical summary[1] for **begin set deflection** with crews in MOPP4-R.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	No Data	6.95444	4.10250	6.07692
Number of Observations		9	4	13
Total Sum of Squares		22.90602	30.51147	75.94127
Residual Sum of Squares		18.66914	30.17866	70.30456
Std. Dev. of Estimate		1.63310	3.88450	2.52811
R-squared		.18497	.01091	.07422
Adjusted R-squared		.06854	-.48364	-.00994
Degrees of Freedom (df)		7	2	11
Number of Ind Vars (K)		2	2	2
F(K-1, df)		1.58862	.02206	.88193
Prob. Value of F		.24791	.89556	.36784
Constant		5.85783	4.63895	5.01214
Standard error		1.02631	4.10121	1.33311
Slope		.33671	-.20643	.34861
Standard error		.26714	1.38999	.37122
t-ratio		1.26041	-.14851	.93911
prob t		.24791	.89556	.36784
Correlation Coefficient		.43008	-.10444	.27244

[1]See Section 4 for discussion of regression equations and units.

Table C-12. ANOVA for **begin set deflection** with crews in MOPP4-R.

	Sum Sq	*DF*	*Mean Sq*
Crew	22.52378	1	53.41749
Error	22.52378	11	4.85613

Mean of Dependent Variable	6.07692
Number of Observations	13
Total Sum of Squares	75.94127
Residual Sum of Squares	53.41749
Std. Dev. of Estimate	2.20366
R-squared	.29659
Adjusted R-squared	.23265
Degrees of Freedom (df)	11
Number of Ind Vars (K)	2
F(K-1, df)	4.63821
Prob. Value of F	.05430

SET DEFLECTION: BATTLE DRESS UNIFORM

(Linear regression with 68 % confidence band)

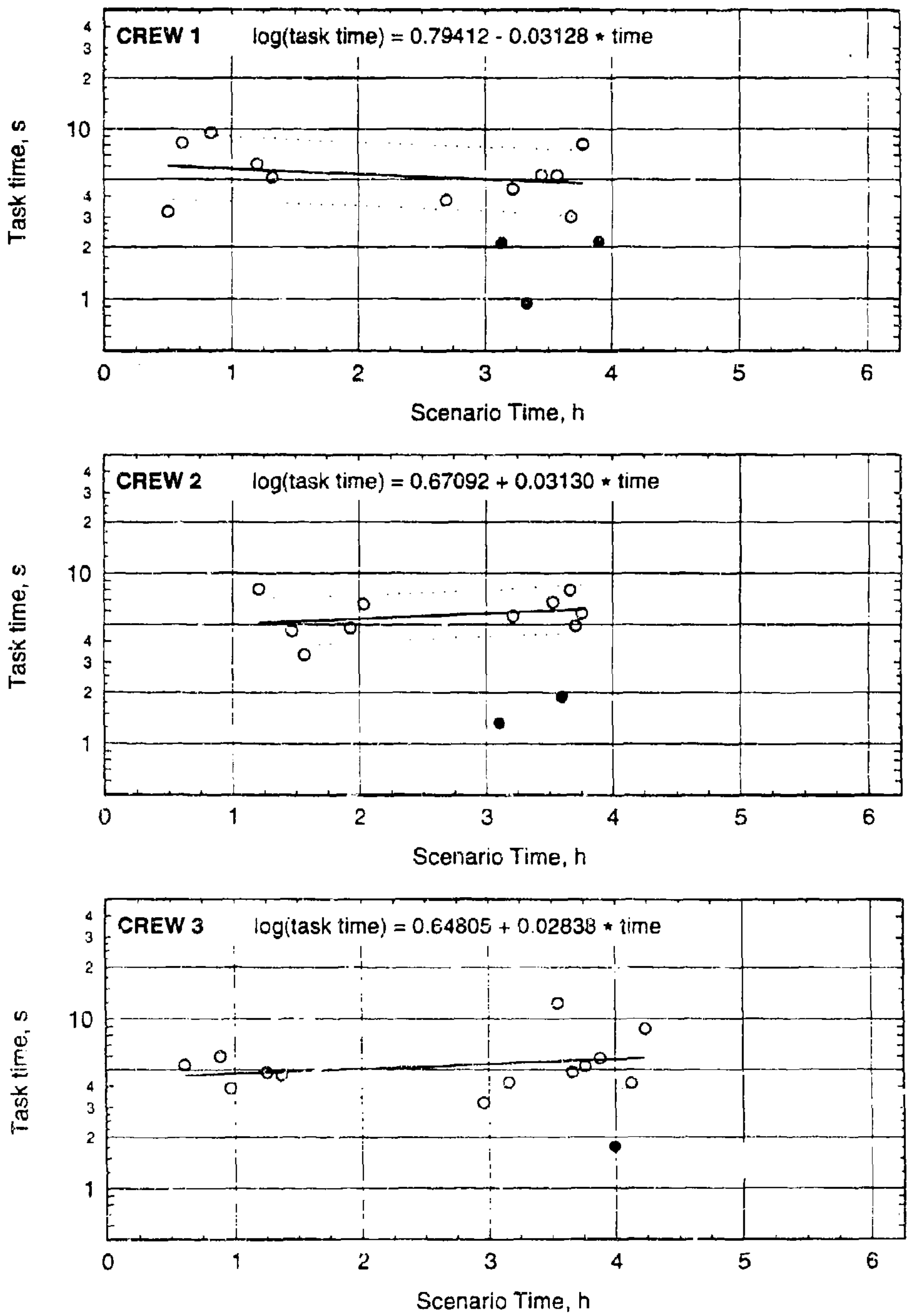


Figure C-13. Task times with regression lines for **set deflection** in BDU.

SET DEFLECTION, ALL CREWS: BATTLE DRESS UNIFORM

(Linear regression with 68 % confidence band)

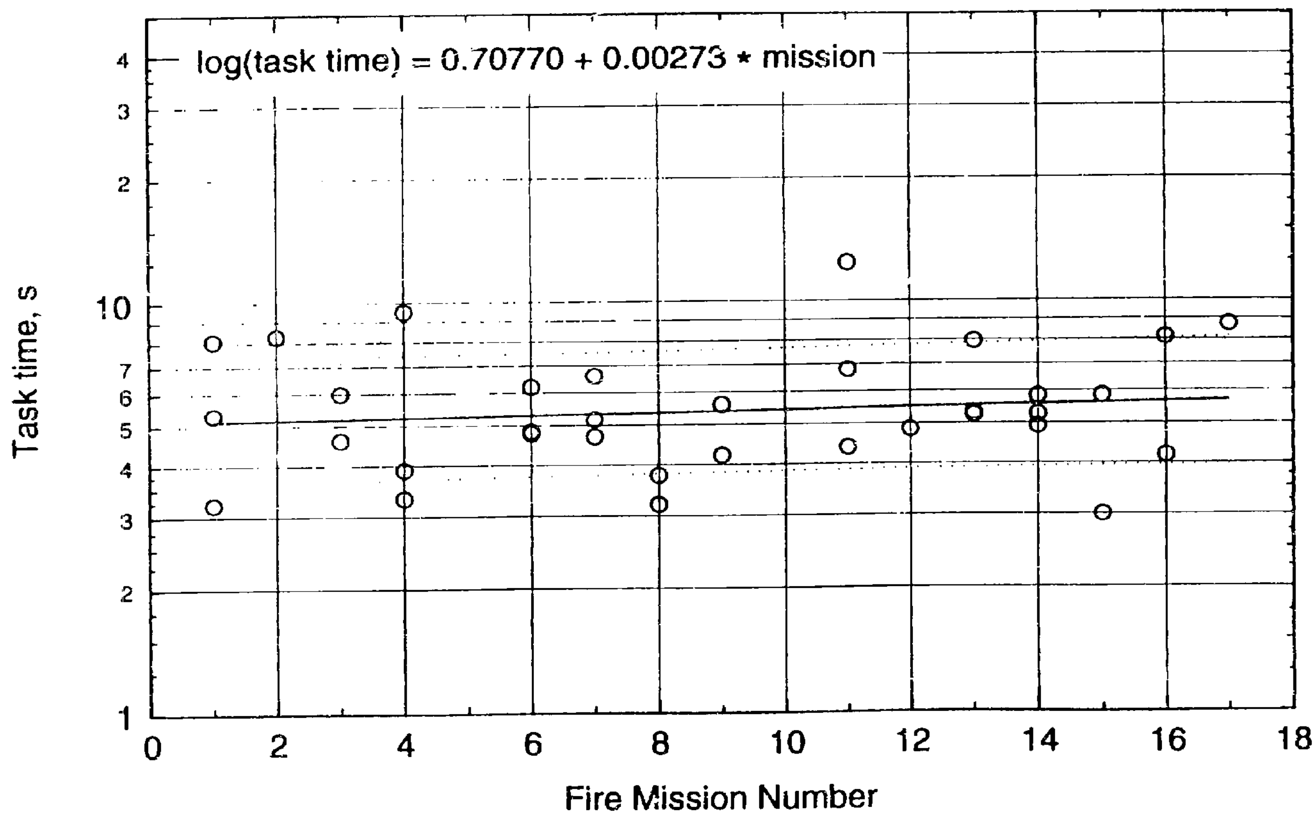


Figure C-14. Aggregate task time data with regression line for **set deflection** in BDU.

Table C-13. Statistical summary[1] for **set deflection** with crews in BDU.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	.72354	.75248	.72316	.73191
Number of Observations	11	10	13	34
Total Sum of Squares	.27715	.12725	.27940	.68979
Residual Sum of Squares	.25922	.11748	.26063	.68376
Std. Dev. of Estimate	.16971	.12118	.15393	.14618
R-squared	.06468	.07676	.06718	.00874
Adjusted R-squared	-.03925	-.03864	-.01763	-.02223
Degrees of Freedom (df)	9	8	11	32
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	.62232	.66518	.79214	.28224
Prob. Value of F	.45046	.43834	.39250	.59891
Constant	.79412	.67092	.64805	.70770
Standard error	.10307	.10710	.09457	.05201
Slope	-.03128	.03130	.02838	.00273
Standard error	.03965	.03838	.03189	.00515
t-ratio	-.78888	.81558	.89002	.53126
prob t	.45046	.43834	.39250	.59891
Correlation Coefficient	-.25431	.27706	.25918	.09350

[1]See Section 4 for discussion of regression equations and units.

Table C-14. ANOVA for **set deflection** with crews in BDU.

	Sum Sq	*DF*	*Mean Sq*
Crew	.00600	2	.68379
Error	.00300	31	.02206

Mean of Dependent Variable	.73191
Number of Observations	34
Total Sum of Squares	.68979
Residual Sum of Squares	.68379
Std. Dev. of Estimate	.14852
R-squared	.00869
Adjusted R-squared	-.05526
Degrees of Freedom (df)	31
Number of Ind Vars (K)	3
F(K-1, df)	.13593
Prob. Value of F	.87342

SET DEFLECTION: MOPP4 - STANDARD

(Linear regression with 68 % confidence band)

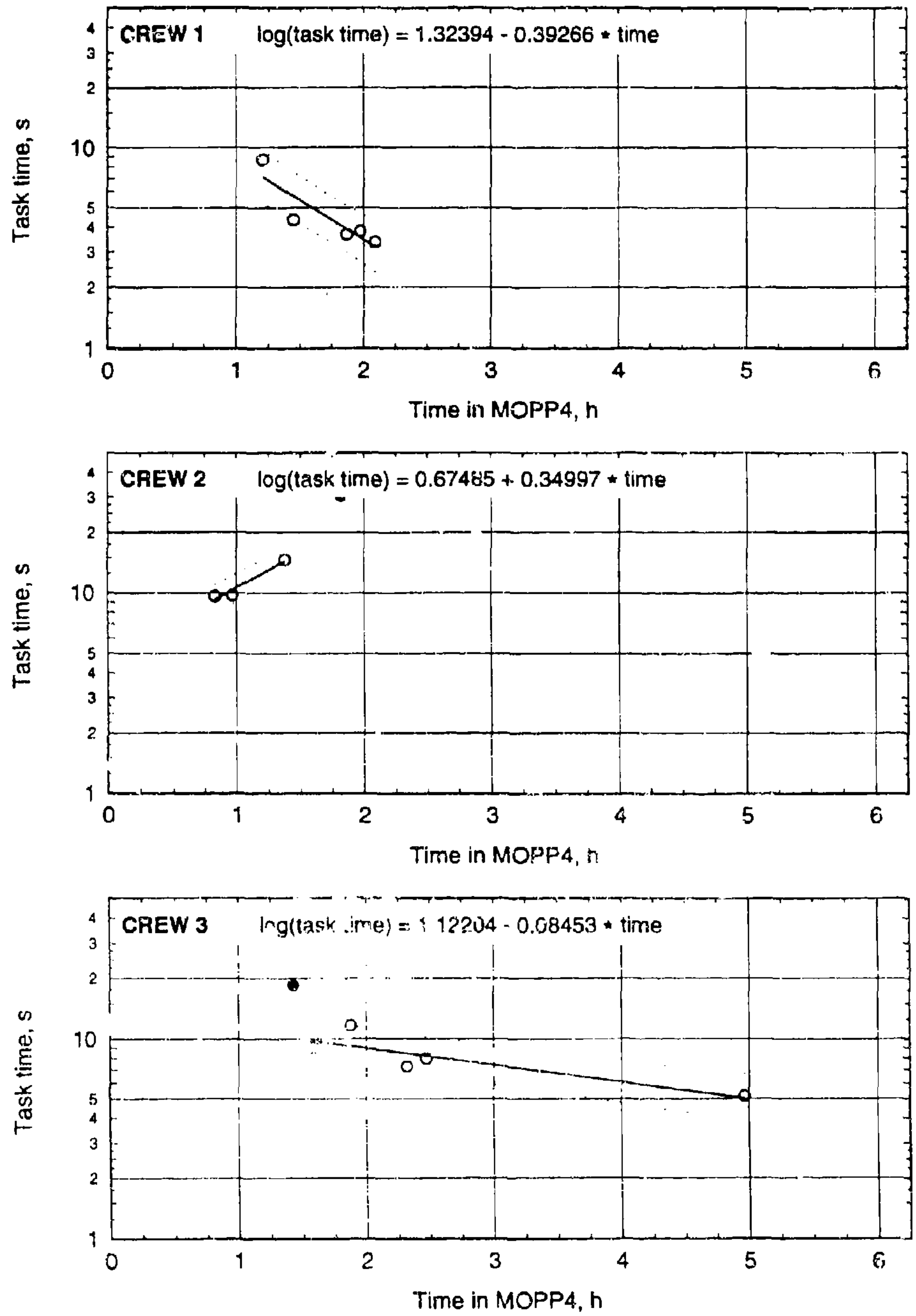


Figure C-15. Task times with regression lines for **set deflection** in MOPP4-S.

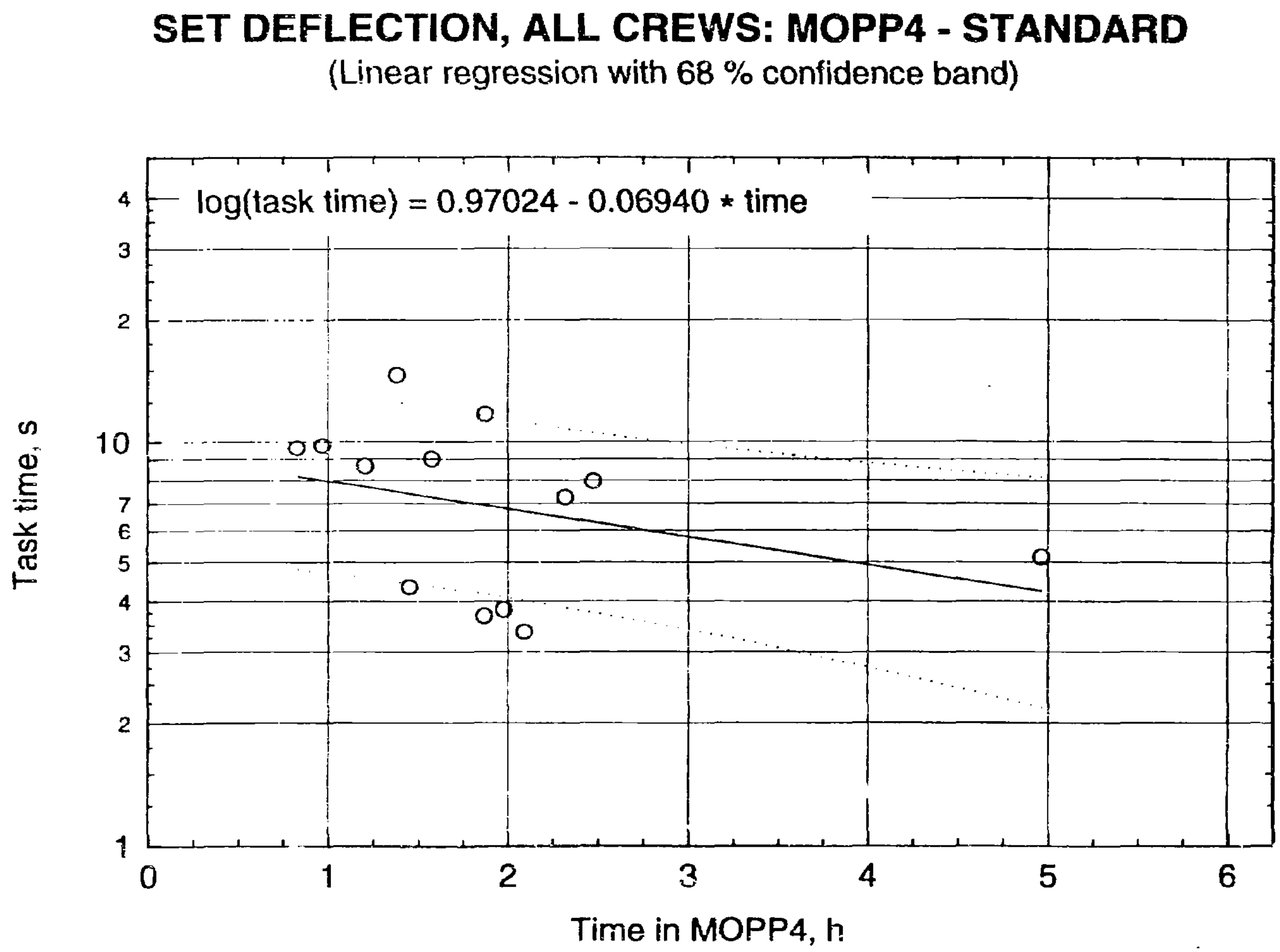


Figure C-16. Aggregate task time data with regression line for **set deflection** in MOPP4-S.

Table C-15. Statistical summary[1] for **set deflection** with crews in MOPP4-S.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	.64985	1.04566	.89894	.83700
Number of Observations	5	3	5	13
Total Sum of Squares	.10981	.02115	.06809	.52398
Residual Sum of Squares	.02333	.00104	.01621	.46136
Std. Dev. of Estimate	.08819	.03218	.07351	.20480
R-squared	.78754	.95101	.76193	.11950
Adjusted R-squared	.71672	.90203	.68257	.03946
Degrees of Freedom (df)	3	1	3	11
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	11.12041	19.41377	9.60126	1.49292
Prob. Value of F	.04456	.14208	.05335	.24730
Constant	1.32394	.67485	1.12204	.97024
Standard error	.20595	.08619	.07915	.12296
Slope	-.39266	.34997	-.08453	-.06940
Standard error	.11775	.07943	.02728	.05680
t-ratio	-3.33473	4.40611	-3.09859	-1.22185
prob t	.04456	.14208	.05335	.24730
Correlation Coefficient	-.88744	.97520	-.87289	-.34569

[1]See Section 4 for discussion of regression equations and units.

Table C-16. ANOVA for **set deflection** with crews in MOPP4-S.

	Sum Sq	*DF*	*Mean Sq*
Crew	.32493	2	.19905
Error	.16246	10	.01991

Mean of Dependent Variable	.83700
Number of Observations	13
Total Sum of Squares	.52398
Residual Sum of Squares	.19905
Std. Dev. of Estimate	.14109
R-squared	.62012
Adjusted R-squared	.54414
Degrees of Freedom (df)	10
Number of Ind Vars (K)	3
F(K-1, df)	8.16191
Prob. Value of F	.00791

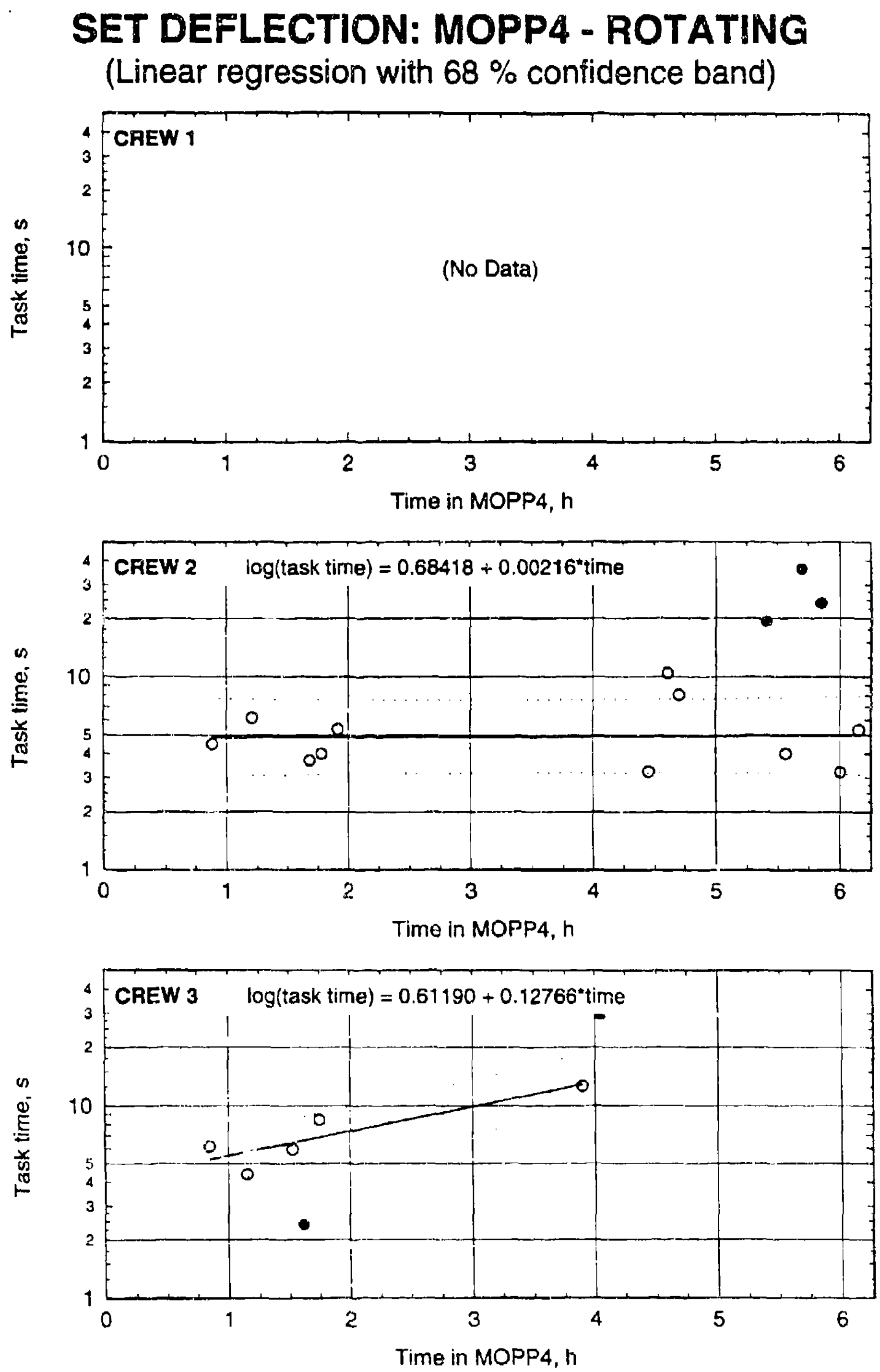


Figure C-17. Task times with regression lines for **set deflection** in MOPP4-R.

SET DEFLECTION, CREWS 2 AND 3: MOPP4 - ROTATING

(Linear regression with 68 % confidence band)

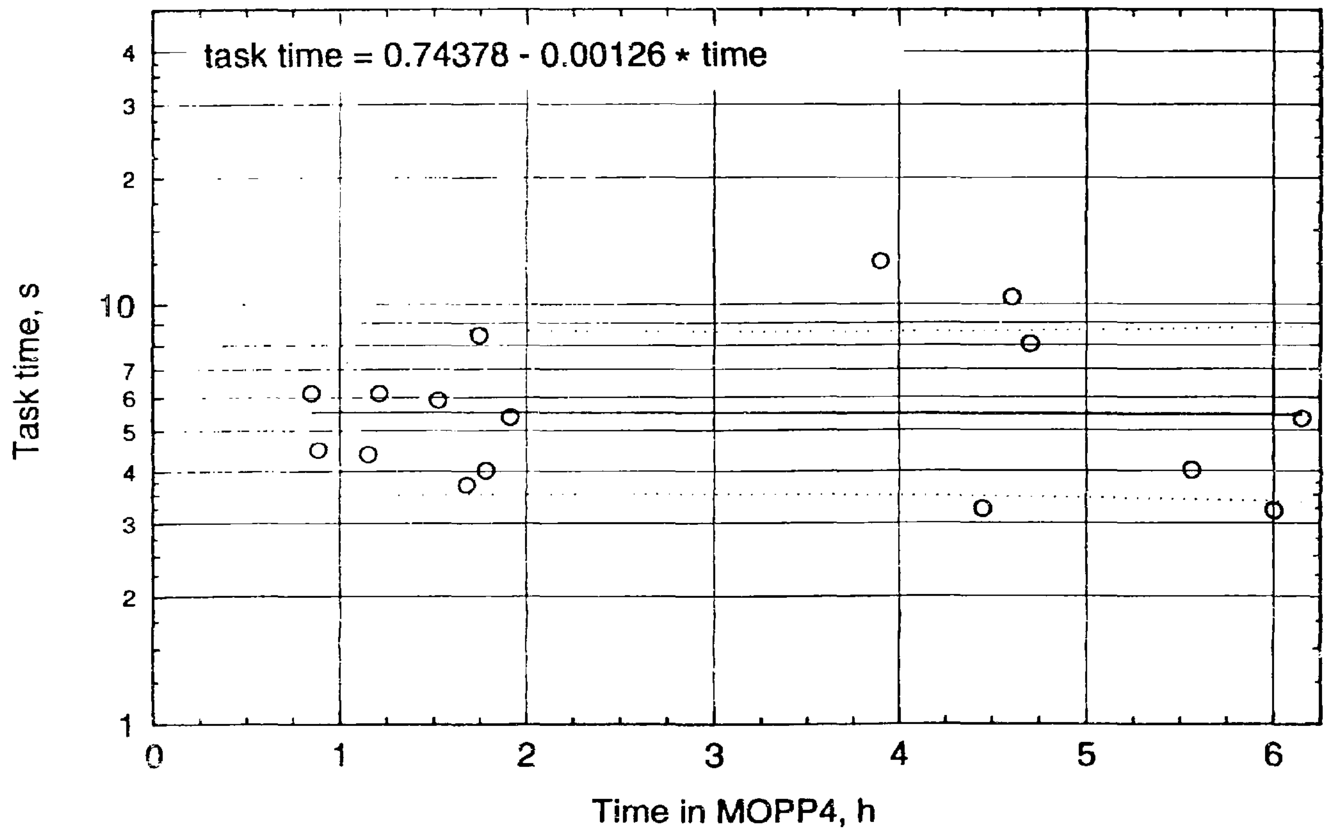


Figure C-18. Aggregate task time data with regression line for **set deflection** in MOPP4-R.

Table C-17. Statistical summary[1] for **set deflection** with crews in MOPP4-R.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	No Data	.69181	.84600	.74000
Number of Observations		11	5	16
Total Sum of Squares		.26309	.12295	.46776
Residual Sum of Squares		.26290	.02831	.46767
Std. Dev. of Estimate		.17091	.09713	.18277
R-squared		.00074	.76979	.00020
Adjusted R-squared		-.11029	.69305	-.07122
Degrees of Freedom (df)		9	3	14
Number of Ind Vars (K)		2	2	2
F(K-1, df)		.00669	10.03153	.00274
Prob. Value of F		.93659	.05059	.95902
Constant		.68418	.61190	.74378
Standard error		.10664	.08573	.08551
Slope		.00216	.12766	-.00126
Standard error		.02637	.04031	.02403
t-ratio		.08180	3.16726	-.05231
prob t		.93659	.05059	.95902
Correlation Coefficient		.02726	.87738	-.01398

[1]See Section 4 for discussion of regression equations and units.

Table C-18. ANOVA for **set deflection** with crews in MOPP4-R.

	Sum Sq	*DF*	*Mean Sq*
Crew	.08172	1	.38605
Error	.08172	14	.02757

Mean of Dependent Variable	.74000
Number of Observations	16
Total Sum of Squares	.46776
Residual Sum of Squares	.38605
Std. Dev. of Estimate	.16606
R-squared	.17469
Adjusted R-squared	.11574
Degrees of Freedom (df)	14
Number of Ind Vars (K)	2
F(K-1, df)	2.96341
Prob. Value of F	.10718

TRAVERSE TUBE: BATTLE DRESS UNIFORM

(Linear regression with 68 % confidence band)

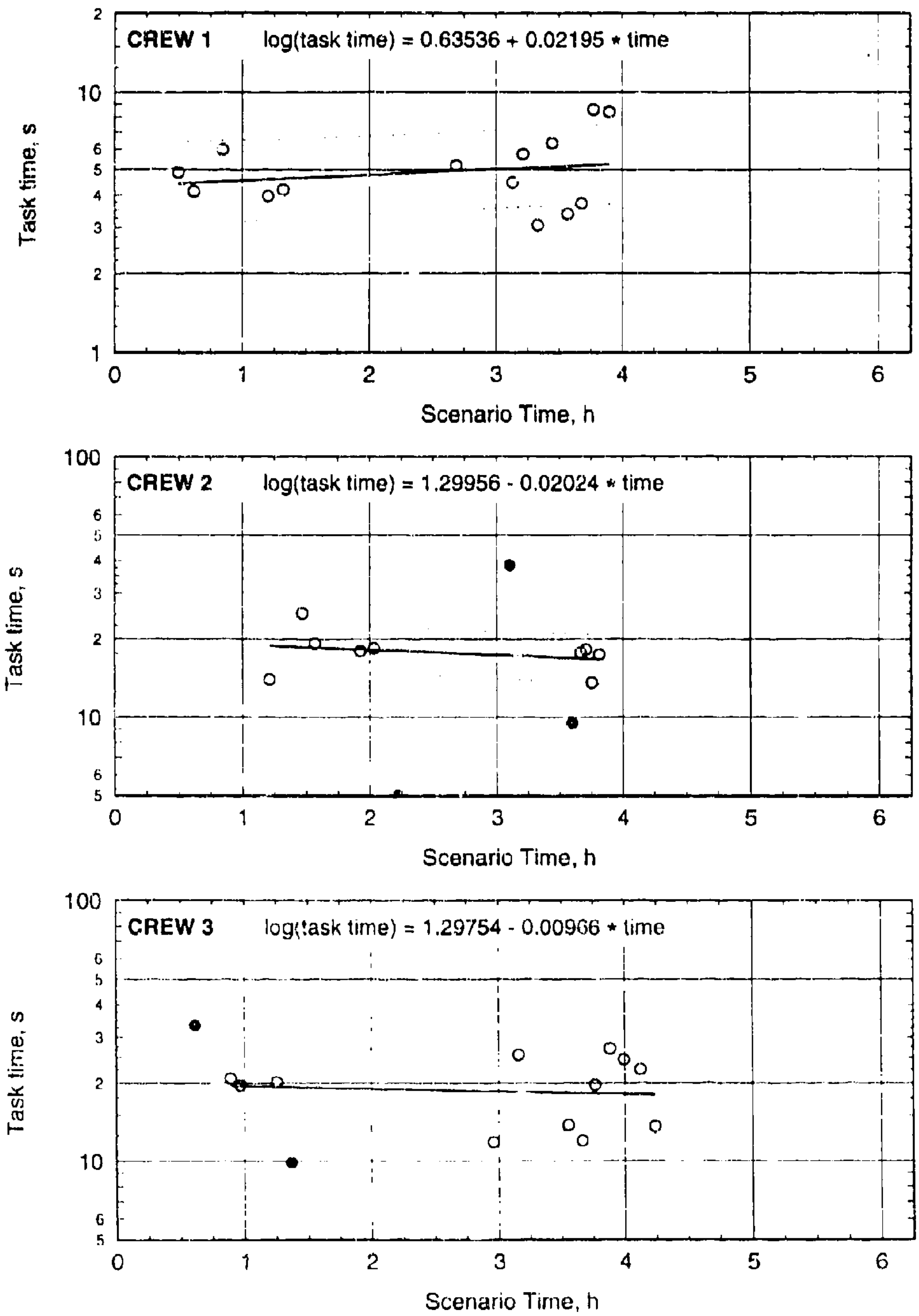


Figure C-19. Task times with regression lines for **traverse tube** in BDU.

TRAVERSE TUBE, CREWS 2 AND 3: BATTLE DRESS UNIFORM

(Linear regression with 68 % confidence band)

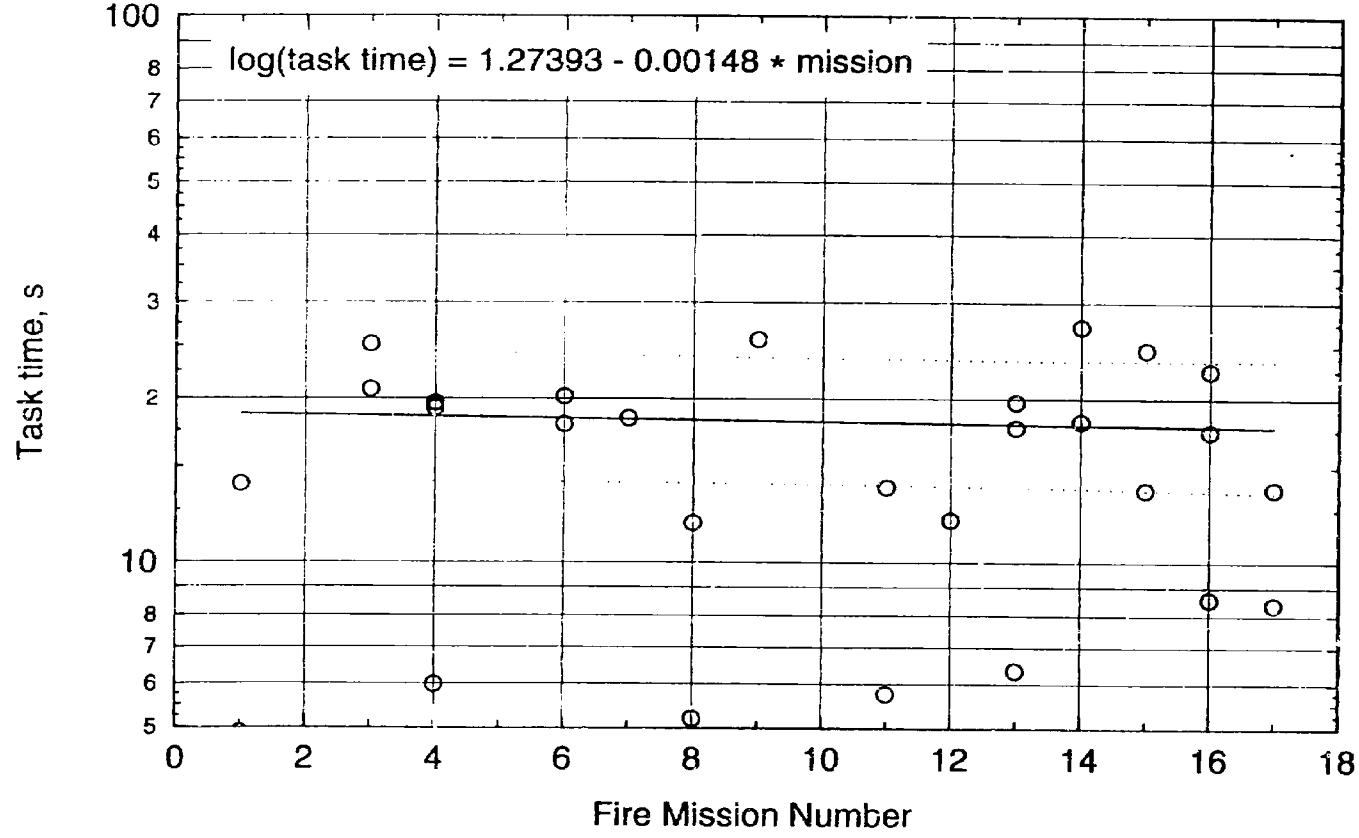


Figure C-20. Aggregate task time data with regression line for **traverse tube** in BDU.

Table C-19. Statistical summary[1] for **traverse tube** with crews in BDU.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	.69054	1.24750	1.26820	1.25933
Number of Observations	14	9	12	21
Total Sum of Squares	.24364	.04905	.18339	.23464
Residual Sum of Squares	.23305	.04487	.18175	.23349
Std. Dev. of Estimate	.13936	.08006	.13482	.11086
R-squared	.04348	.08518	.00892	.00489
Adjusted R-squared	-.03623	-.04551	-.09019	-.04749
Degrees of Freedom (df)	12	7	10	19
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	.54551	.65179	.08999	.09333
Prob. Value of F	.47436	.44603	.77033	.76330
Constant	.63536	1.29956	1.29754	1.27393
Standard error	.08348	.06979	.10527	.05357
Slope	.02195	-.02024	-.00966	-.00148
Standard error	.02972	.02507	.03221	.00485
t-ratio	.73859	-.80734	-.29999	-.30551
prob t	.47436	.44603	.77033	.76330
Correlation Coefficient	.20852	-.29186	-.09444	-.06992

[1]See Section 4 for discussion of regression equations and units.

Table C-20. ANOVA for **traverse tube** with crews in BDU.

	Sum Sq	*DF*	*Mean Sq*
Crew	.00220	1	.23244
Error	.00220	19	.01223

Mean of Dependent Variable	1.25933
Number of Observations	21
Total Sum of Squares	.23464
Residual Sum of Squares	.23244
Std. Dev. of Estimate	.11061
R-squared	.00939
Adjusted R-squared	-.04275
Degrees of Freedom (df)	19
Number of Ind Vars (K)	2
F(K-1, df)	.18010
Prob. Value of F	.67605

TRAVERSE TUBE: MOPP4 - STANDARD

(Linear regression with 68 % confidence band)

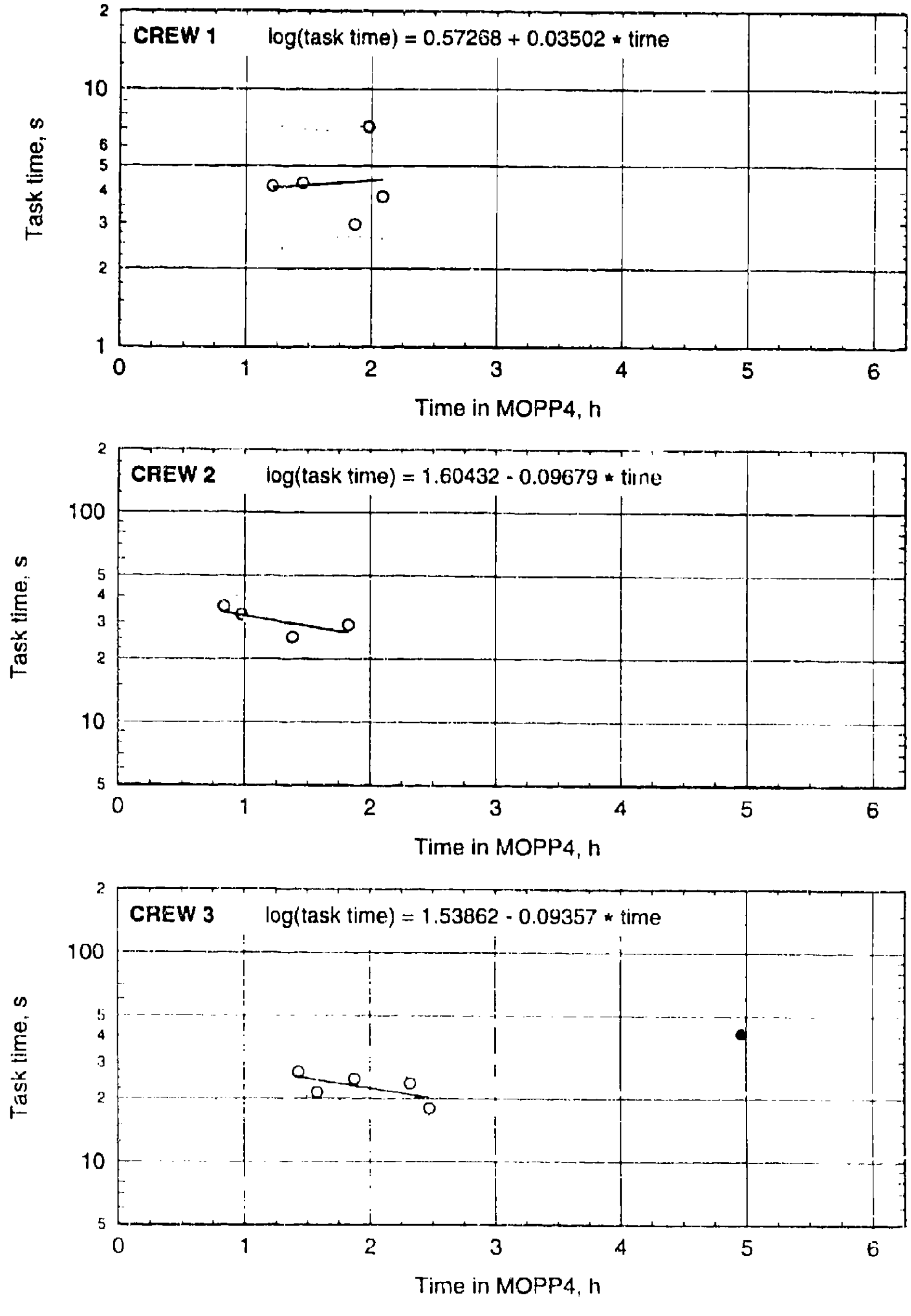


Figure C-21. Task times with regression lines for **traverse tube** in MOPP4-S.

TRAVERSE TUBE, CREWS 2 AND 3: MOPP4 - STANDARD

(Linear regression with 68 % confidence band)

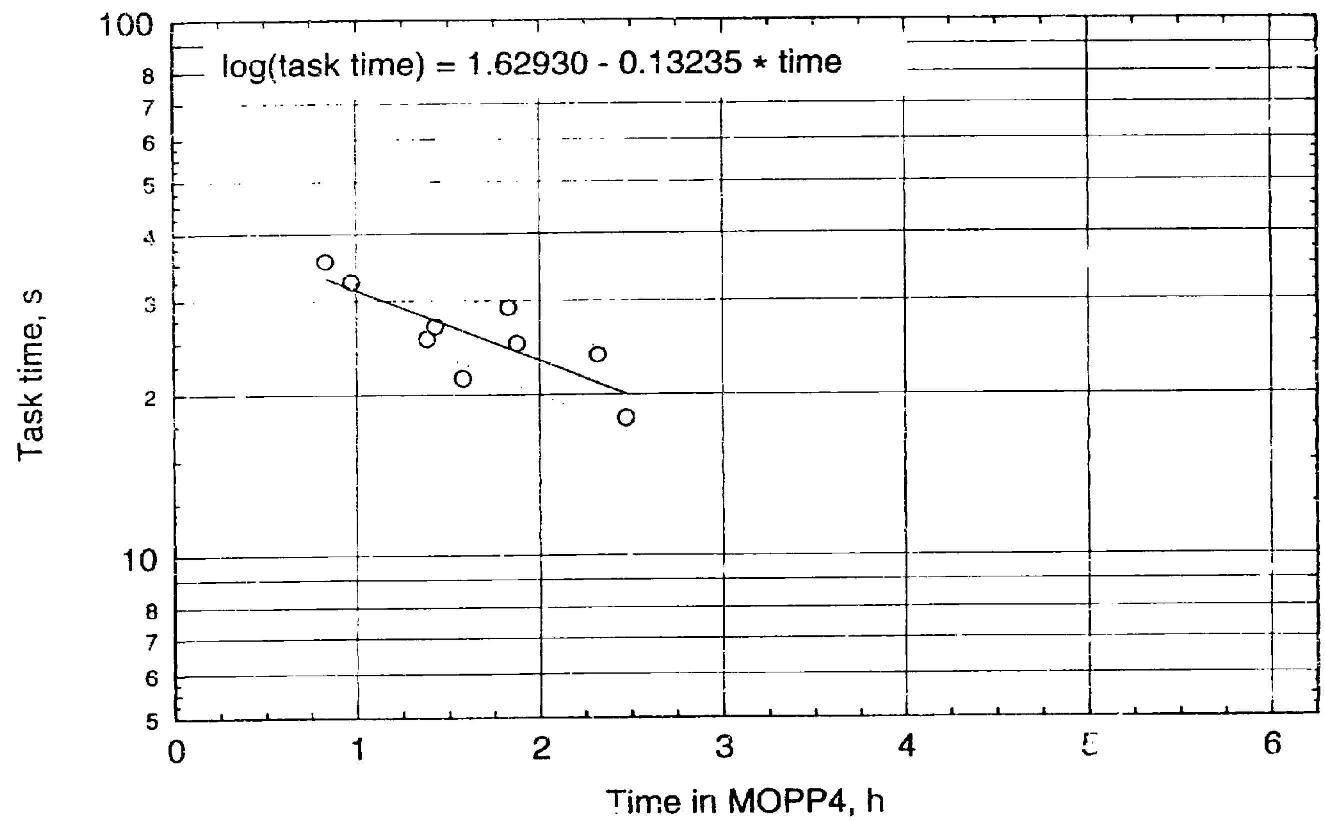


Figure C-22. Aggregate task time data with regression line for **traverse tube** in MOPP4-S.

Table C-21. Statistical summary[1] for **traverse tube** with crews in MOPP4-S.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	.63285	1.48299	1.35762	1.41334
Number of Observations	5	4	5	9
Total Sum of Squares	.07778	.01184	.01784	.06461
Residual Sum of Squares	.07709	.00620	.01063	.02159
Std. Dev. of Estimate	.16030	.05569	.05951	.05554
R-squared	.00882	.47622	.40440	.66578
Adjusted R squared	-.32157	.21433	.20587	.61804
Degrees of Freedom (df)	3	2	3	7
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	.02670	1.81841	2.03696	13.94440
Prob. Value of F	.88059	.30991	.24880	.00732
Constant	.57268	1.60432	1.53862	1.62930
Standard error	.37516	.09419	.12958	.06072
Slope	.03502	-.09679	-.09357	-.13235
Standard error	.21434	.07178	.06556	.03544
t-ratio	.16340	-1.34848	-1.42722	-3.73422
prob t	.88059	.30991	.24880	.00732
Correlation Coefficient	.09392	-.69009	-.63593	-.81595

[1]See Section 4 for discussion of regression equations [illegible] units.

Table C-22. ANOVA for **traverse tube** with crews in MOPP4-S.

	Sum Sq	*DF*	*Mean Sq*
Crew	.03492	1	.02968
Error	.03492	7	.00424

Mean of Dependent Variable	1.41334
Number of Observations	9
Total Sum of Squares	.06461
Residual Sum of Squares	.02968
Std. Dev. of Estimate	.06512
R-squared	.54056
Adjusted R-squared	.47492
Degrees of Freedom (df)	7
Number of Ind Vars (K)	2
F(K-1, df)	8.23587
Prob. Value of F	.02400

TRAVERSE TUBE: MOPP4 - ROTATING

(Linear regression with 68 % confidence band)

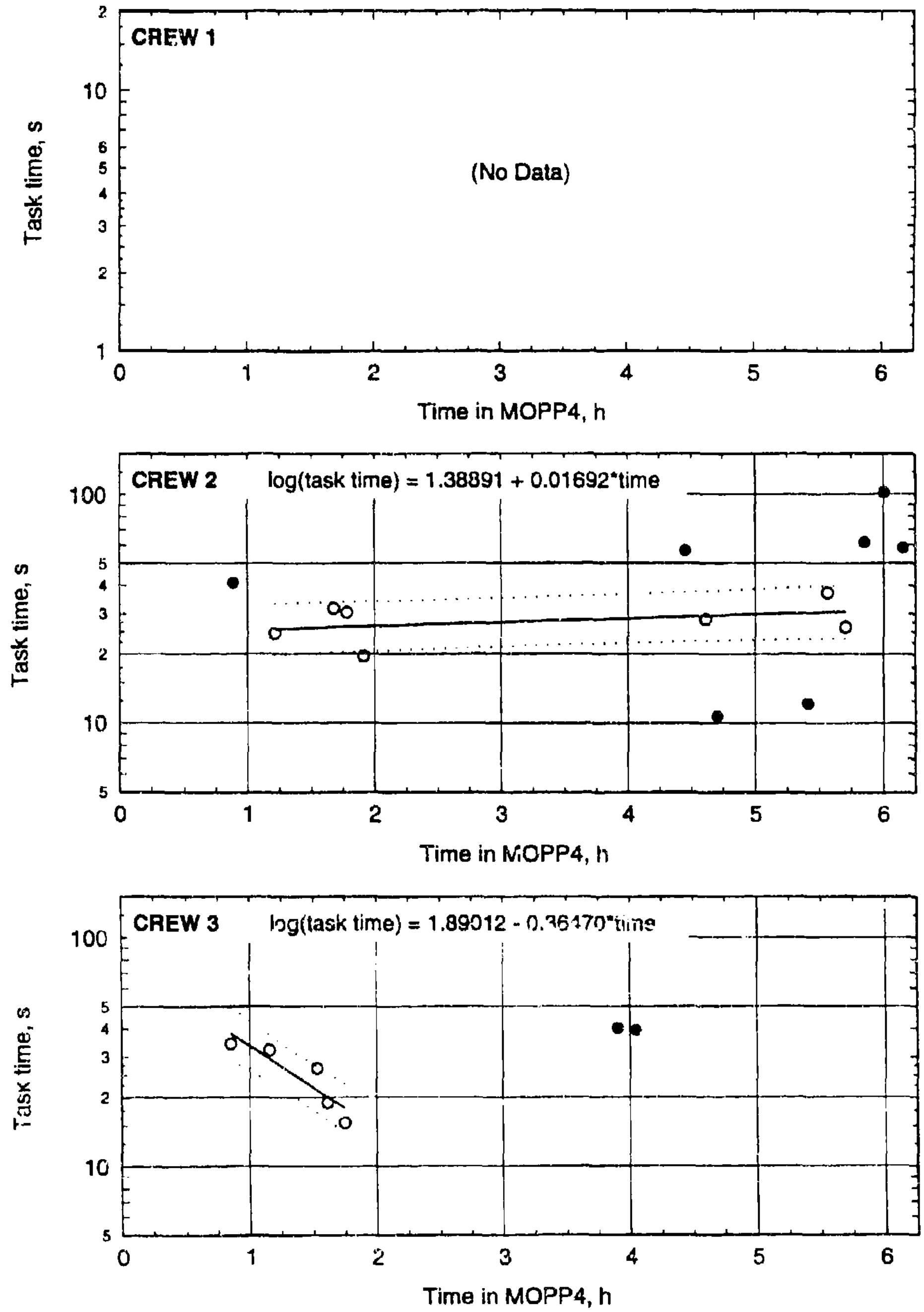


Figure C-23. Task times with regression lines for **traverse tube** in MOPP4-R.

TRAVERSE TUBE, CREWS 2 AND 3: MOPP4 - ROTATING

(Linear regression with 68 % confidence band)

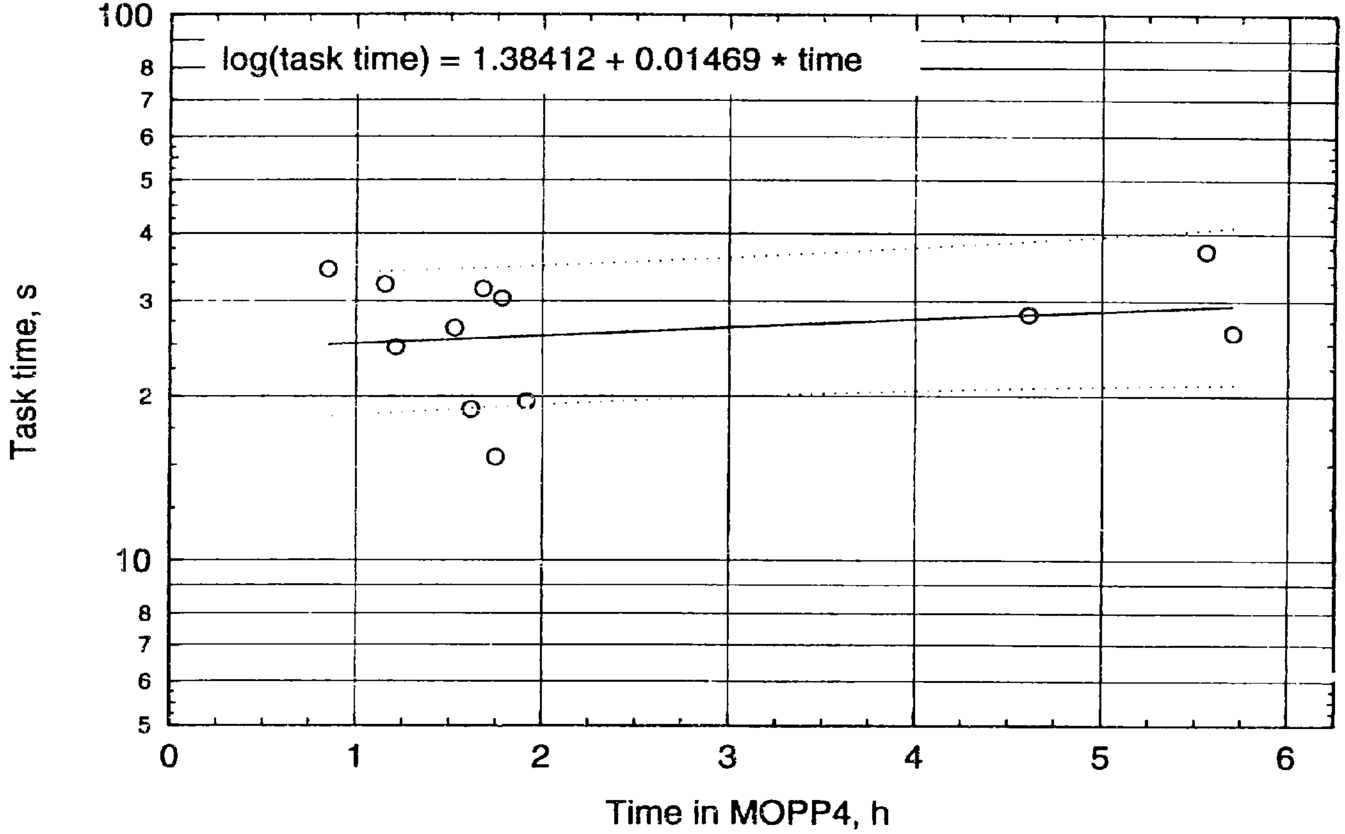


Figure C-24. Aggregate task time data with regression line for **traverse tube** in MOPP4-R.

Table C-23. Statistical summary[1] for **traverse tube** with crews in MOPP4-R.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	No Data	1.44322	1.38765	1.42006
Number of Observations		7	5	12
Total Sum of Squares		.04689	.08919	.14508
Residual Sum of Squares		.04008	.01696	.13772
Std. Dev. of Estimate		.08953	.07520	.11735
R-squared		.14521	.80980	.05076
Adjusted R-squared		-.02575	.74640	-.04417
Degrees of Freedom (df)		5	3	10
Number of Ind Vars (K)		2	2	2
F(K-1, df)		.84939	12.77292	.53471
Prob. Value of F		.39901	.03745	.48142
Constant		1.38891	1.89012	1.38412
Standard error		.06794	.14456	.05970
Slope		.01692	-.36470	.01469
Standard error		.01836	.10204	.02009
t-ratio		.92162	-3.57392	.73124
prob t		.39901	.03745	.48142
Correlation Coefficient		.38106	-.89989	.22529

[1]See Section 4 for discussion of regression equations and units.

Table C-24. ANOVA for **traverse tube** with crews in MOPP4-R.

	Sum Sq	*DF*	*Mean Sq*
Crew	.00901	1	.13608
Error	.00901	10	.01361

Mean of Dependent Variable	1.42006
Number of Observations	12
Total Sum of Squares	.14508
Residual Sum of Squares	.13608
Std. Dev. of Estimate	.11665
R-squared	.06207
Adjusted R-squared	-.03172
Degrees of Freedom (df)	10
Number of Ind Vars (K)	2
F(K-1, df)	.66178
Prob. Value of F	.43488

BEGIN SET ELEVATION: BATTLE DRESS UNIFORM

(Linear regression with 68 % confidence band)

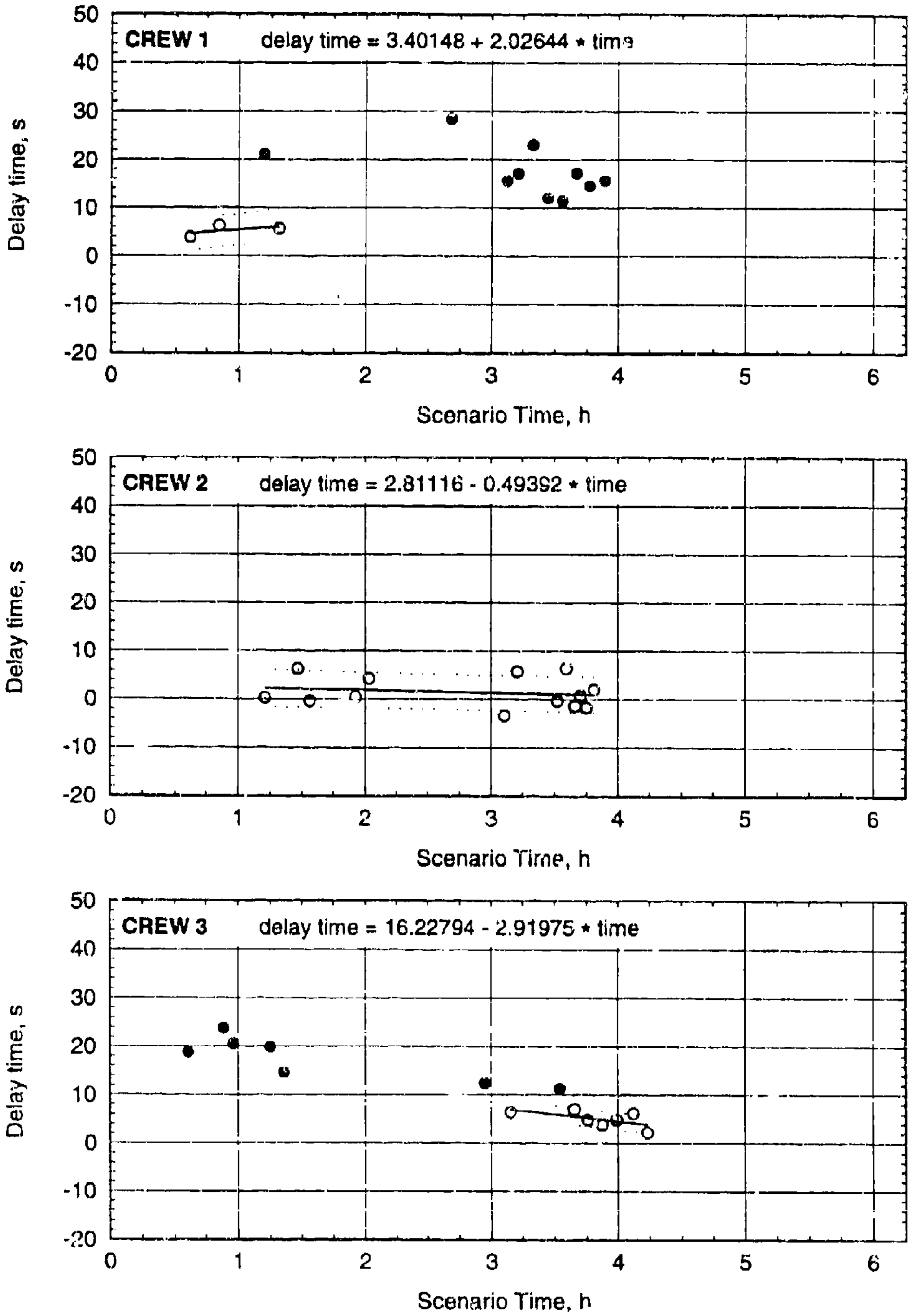


Figure C-25. Task times with regression lines for **begin set elevation** in BDU.

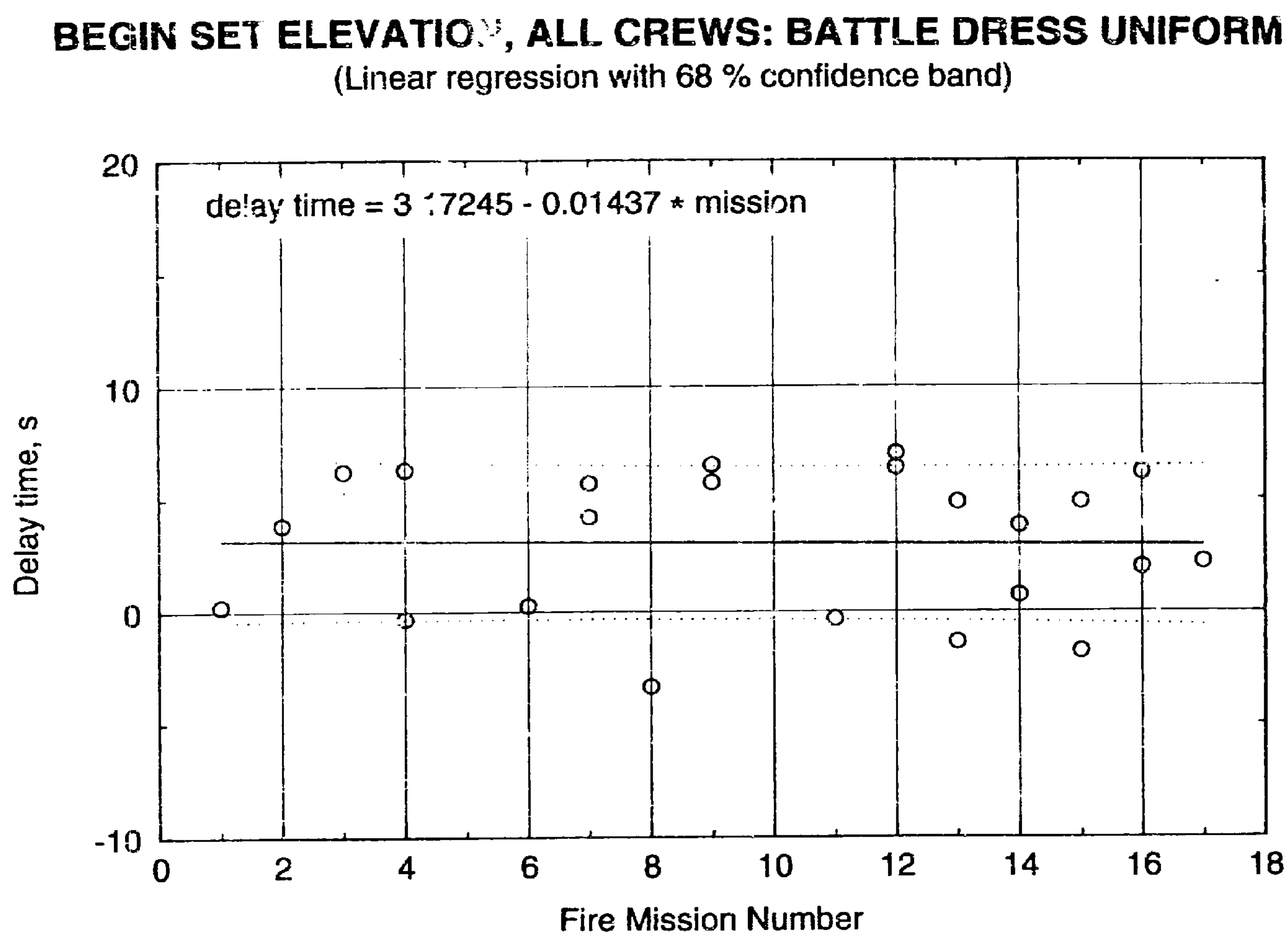


Figure C-26. Aggregate task time data with regression line for **begin set elevation** in BDU.

Table C-25. Statistical summary[1] for **begin set elevation** with crews in BDU.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	5.27333	1.42231	5.05429	3.03000
Number of Observations	3	13	7	23
Total Sum of Squares	3.26167	124.18100	16.99797	221.82320
Residual Sum of Squares	2.20393	121.23260	10.48416	221.71250
Std. Dev. of Estimate	1.48456	3.31981	1.44804	3.24927
R-squared	.32429	.02374	.38321	.00050
Adjusted R-squared	-.35141	-.06501	.25985	-.04710
Degrees of Freedom (df)	1	11	5	21
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	.47993	.26752	3.10650	.01048
Prob. Value of F	.61430	.61524	.13827	.91943
Constant	3.40148	2.81116	16.22794	3.17245
Standard error	2.83465	2.83867	6.36314	1.54767
Slope	2.02644	-.49392	-2.91975	-.01437
Standard error	2.92511	.95495	1.65657	.14037
t-ratio	.69277	-.51723	-1.76253	-.10237
prob t	.61430	.61524	.13827	.91943
Correlation Coefficient	.56947	-.15409	-.61904	-.02233

[1]See Section 4 for discussion of regression equations and units.

Table C-26. ANOVA for **begin set elevation** with crews in BDU.

	Sum Sq	*DF*	*Mean Sq*
Crew	77.38252	2	144.44060
Error	38.69126	20	7.22203

Mean of Dependent Variable	3.03000
Number of Observations	23
Total Sum of Squares	221.82320
Residual Sum of Squares	144.44060
Std. Dev. of Estimate	2.68738
R-squared	.34885
Adjusted R-squared	.28373
Degrees of Freedom (df)	20
Number of Ind Vars (K)	3
F(K-1, df)	5.35739
Prob. Value of F	.01370

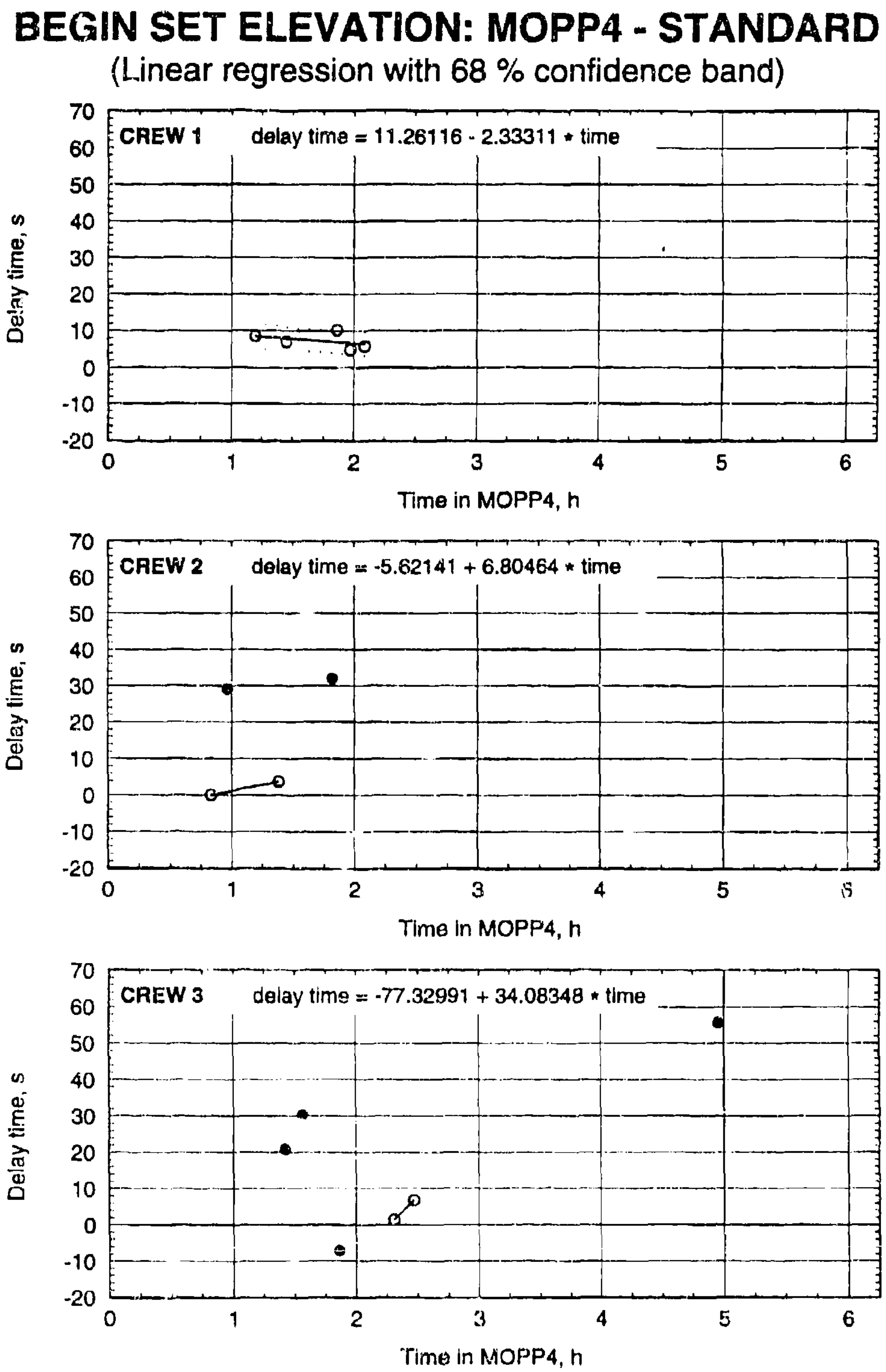


Figure C-27. Task times with regression lines for **begin set elevation** in MOPP4-S.

BEGIN SET ELEVATION, ALL CREWS: MOPP4 - STANDARD

(Linear regression with 68 % confidence band)

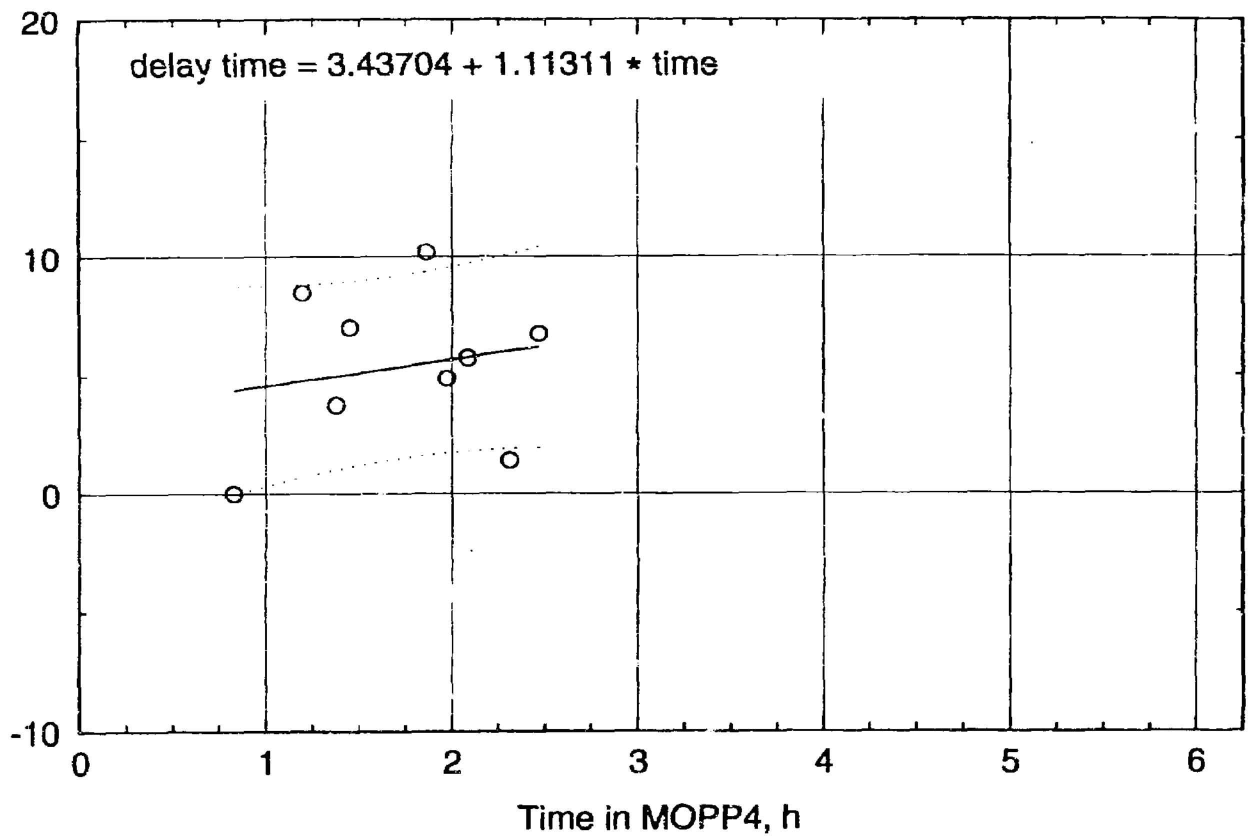


Figure C-28. Aggregate task time data with regression line for **begin set elevation** in MOPP4-S.

Table C-27. Statistical summary[1] for **begin set elevation** with crews in MOPP4-S.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	7.26400	1.88000	4.08000	5.36000
Number of Observations	5	2	2	9
Total Sum of Squares	18.20732	6.99380	14.36480	85.18959
Residual Sum of Squares	15.13328	.00000	.00000	82.23502
Std. Dev. of Estimate	2.24598	.00000	.00000	3.42752
R-squared	.16884	1.00000	1.00000	.03468
Adjusted R-squared	-.10822	.00000	.00000	-.10322
Degrees of Freedom (df)	3	0	0	7
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	.60939			.25150
Prob. Value of F	.49195			.63141
Constant	11.26116	-5.62141	-77.32991	3.43704
Standard error	5.21798			4.00104
Slope	-2.33311	6.80464	34.08348	1.11311
Standard error	2.98873			2.21957
t-ratio	-.78064			.50150
prob t	.49195			.63141
Correlation Coefficient	-.41090	1.00000	1.00000	.18623

[1]See Section 4 for discussion of regression equations and units.

Table C-28. ANOVA for **begin set elevation** with crews in MOPP4-S.

	Sum Sq	*DF*	*Mean Sq*
Crew	45.62367	2	39.56591
Error	22.81184	6	6.59432

Mean of Dependent Variable	5.36000
Number of Observations	9
Total Sum of Squares	85.18959
Residual Sum of Squares	39.56591
Std. Dev. of Estimate	2.56794
R-squared	.53555
Adjusted R-squared	.38074
Degrees of Freedom (df)	6
Number of Ind Vars (K)	3
F(K-1, df)	3.45932
Prob. Value of F	.10019

BEGIN SET ELEVATION: MOPP4 - ROTATING

(Linear regression with 68 % confidence band)

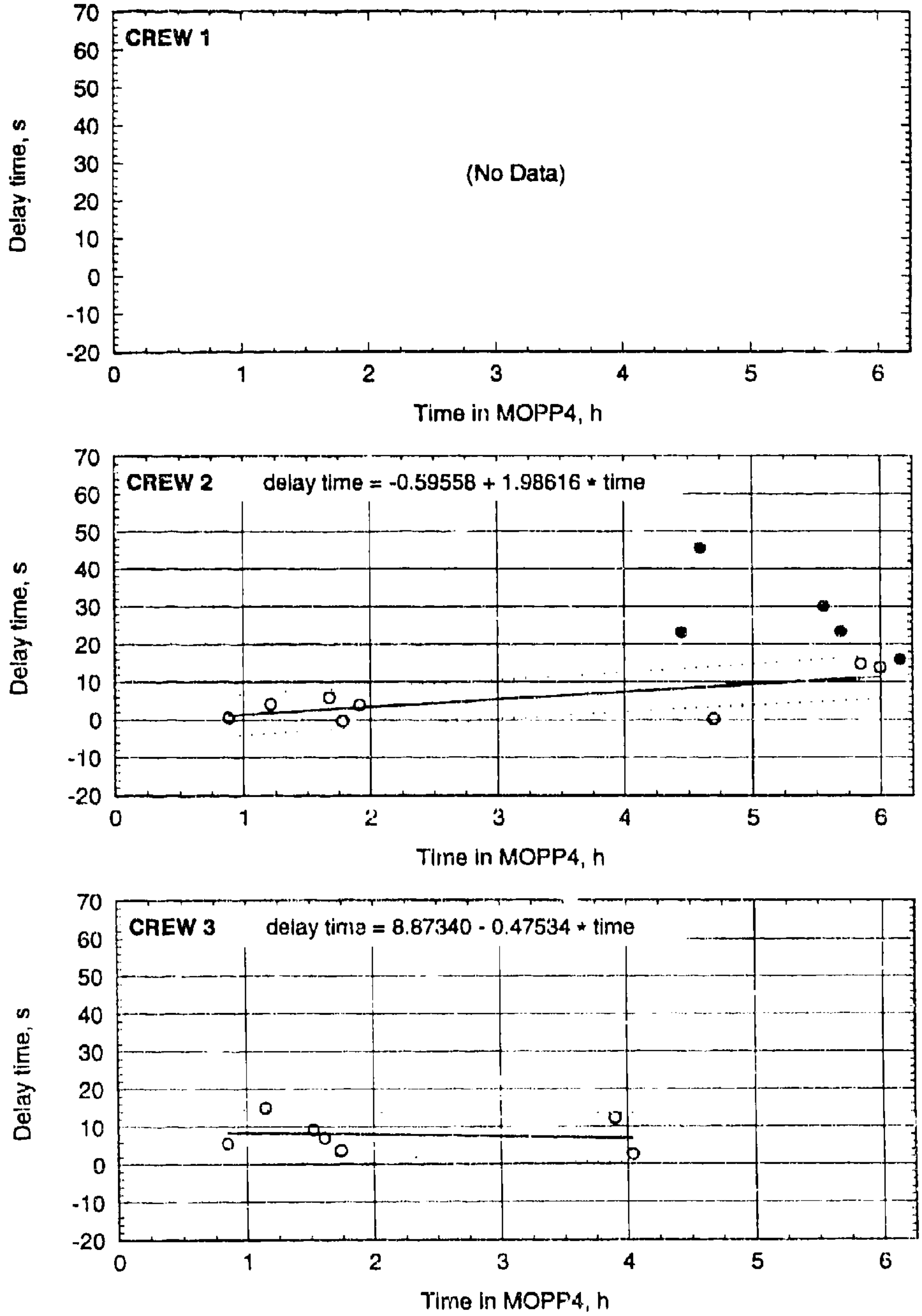


Figure C-29. Task times with regression lines for **begin set elevation** in MOPP4-R.

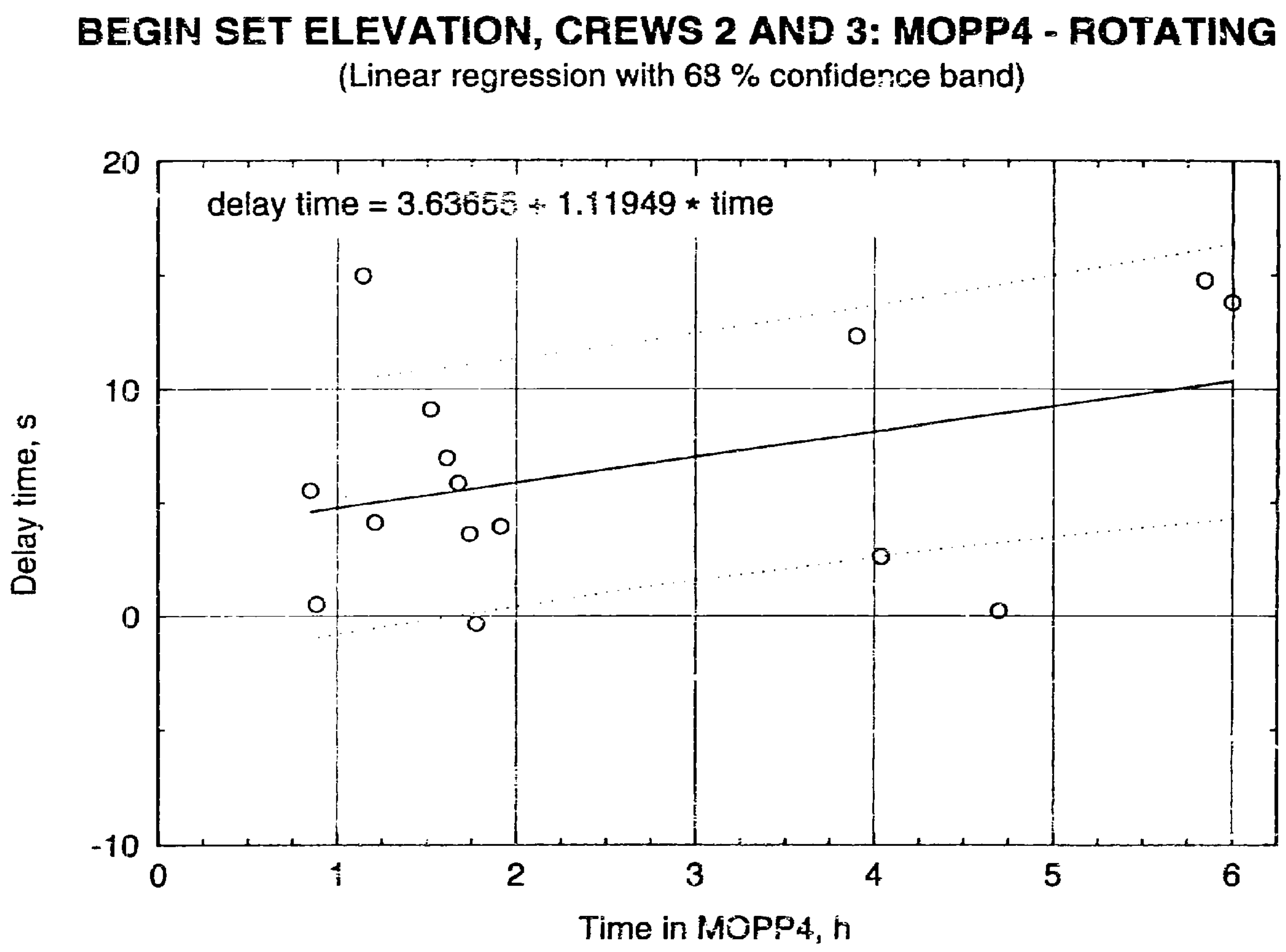


Figure C-30. Aggregate task time data with regression line for **begin set elevation** in MOPP4-R.

Table C-29. Statistical summary[1] for **begin set elevation** with crews in MOPP4-R.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	No Data	5.36250	7.86857	6.53200
Number of Observations		8	7	15
Total Sum of Squares		246.53890	123.84730	393.83300
Residual Sum of Squares		119.95470	121.54620	337.18210
Std. Dev. of Estimate		4.47129	4.93044	5.09285
R-squared		.51345	.01858	.14384
Adjusted R-squared		.43235	-.17770	.07799
Degrees of Freedom (df)		6	5	13
Number of Ind Vars (K)		2	2	2
F(K-1, df)		6.33160	.09466	2.18417
Prob. Value of F		.04552	.77074	.16325
Constant		-.59558	8.87340	3.63655
Standard error		2.84704	3.76022	2.35956
Slope		1.98616	-.47534	1.11949
Standard error		.78933	1.54497	.75749
t-ratio		2.51627	-.30767	1.47789
prob t		.04552	.77074	.16325
Correlation Coefficient		.71655	-.13631	.37927

[1]See Section 4 for discussion of regression equations and units.

Table C-30. ANOVA for **begin set elevation** with crews in MOPP4-R.

	Sum Sq	*DF*	*Mean Sq*
Crew	23.44680	1	370.38620
Error	23.44680	13	28.49125

Mean of Dependent Variable	6.53200
Number of Observations	15
Total Sum of Squares	393.83300
Residual Sum of Squares	370.38620
Std. Dev. of Estimate	5.33772
R-squared	.05953
Adjusted R-squared	-.01281
Degrees of Freedom (df)	13
Number of Ind Vars (K)	2
F(K-1, df)	.82295
Prob. Value of F	.38083

SET ELEVATION: BATTLE DRESS UNIFORM

(Linear regression with 68 % confidence band)

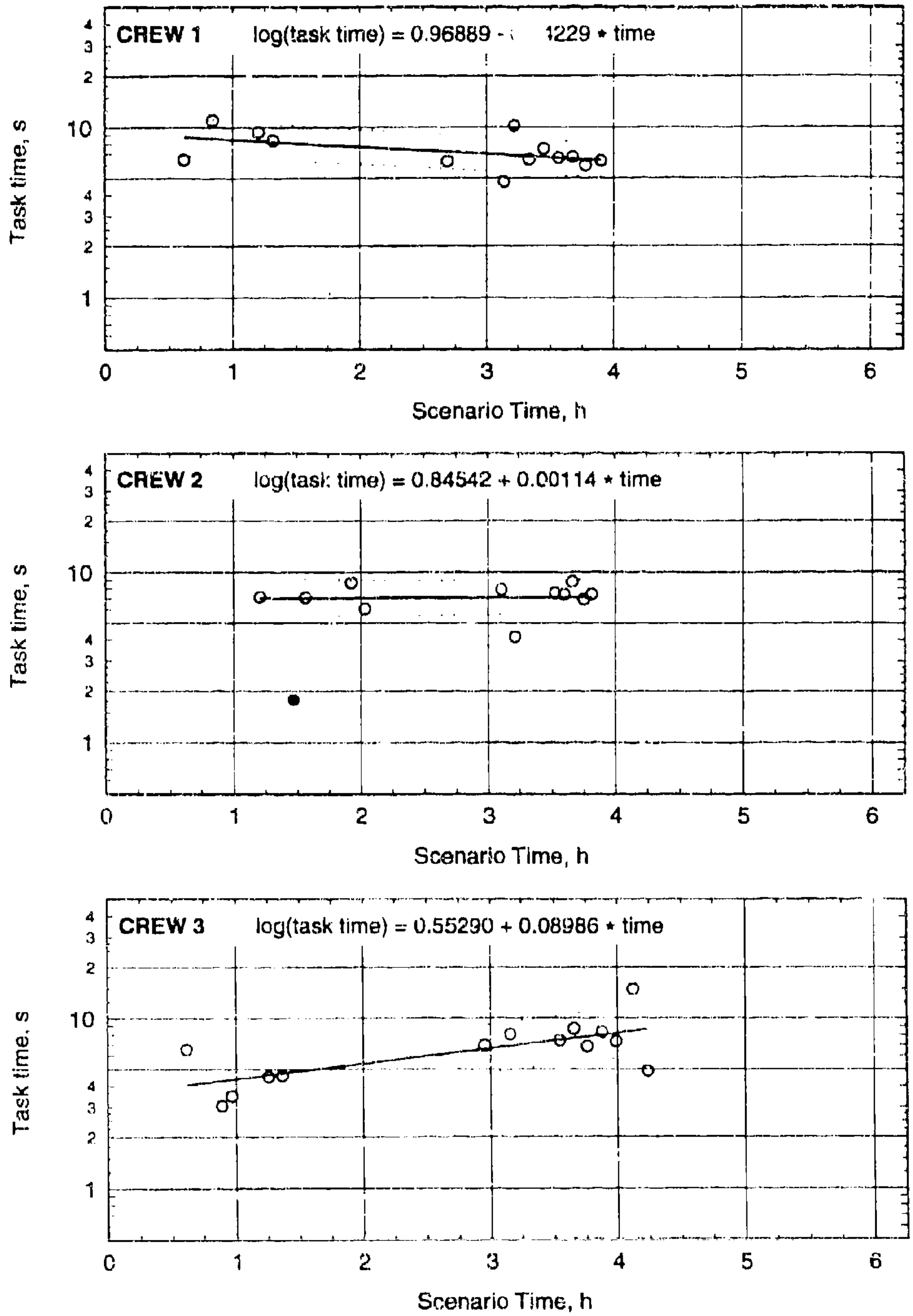


Figure C-31. Task times with regression lines for **set elevation** in BDU.

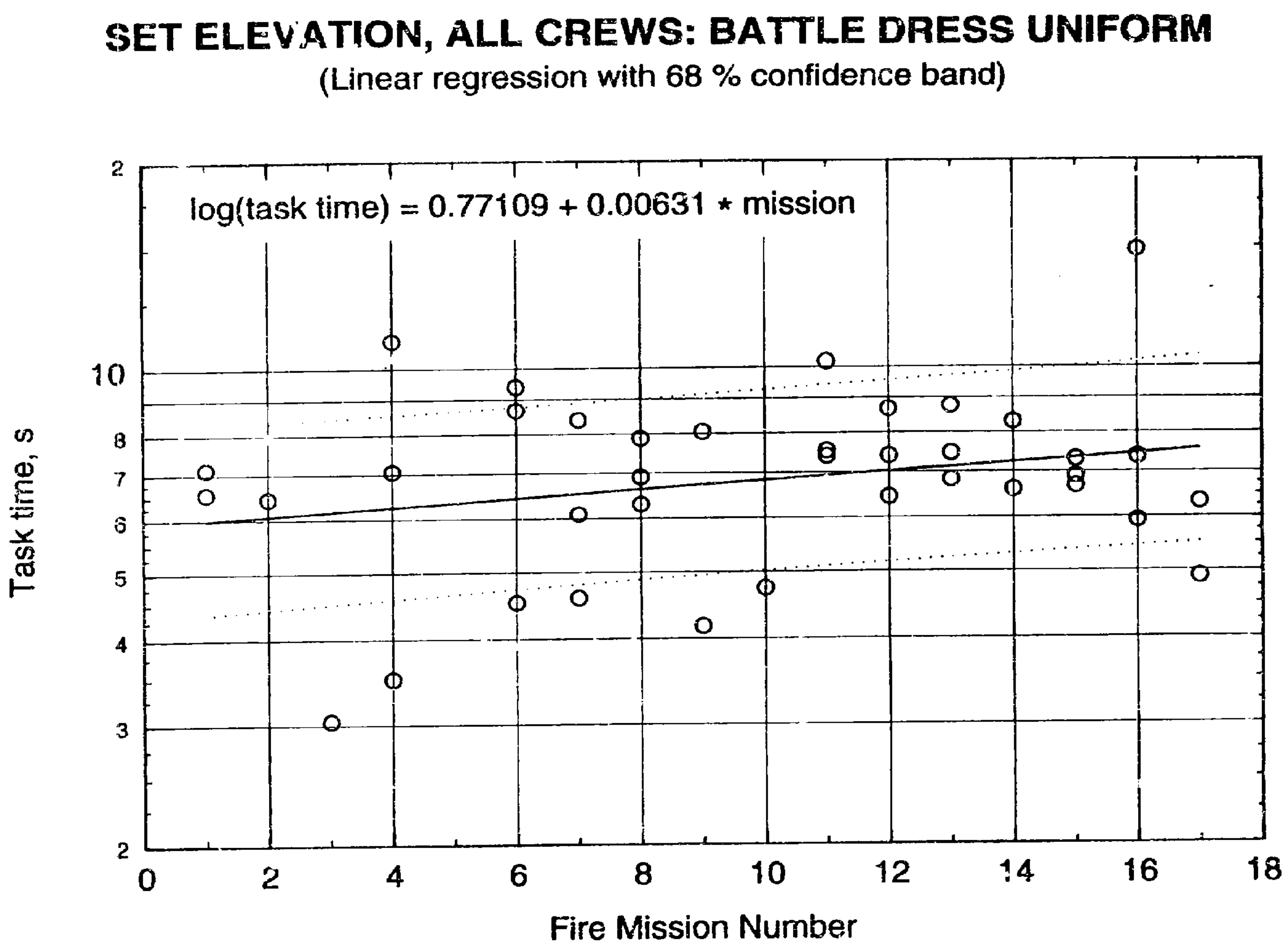


Figure C-32. Aggregate task time data with regression line for **set elevation** in BDU.

Table C-31. Statistical summary[1] for **set elevation** with crews in BDU.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	.85598	.84868	.79929	.83298
Number of Observations	13	11	14	38
Total Sum of Squares	.12763	.07704	.41178	.64192
Residual Sum of Squares	.09609	.07703	.21033	.60909
Std. Dev. of Estimate	.09346	.09251	.13239	.13007
R-squared	.24712	.00016	.48921	.05115
Adjusted R-squared	.17868	-.11093	.44665	.02479
Degrees of Freedom (df)	11	9	12	36
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	3.61054	.00145	11.49308	1.94056
Prob. Value of F	.08393	.97047	.00537	.17215
Constant	.96889	.84542	.55290	.77109
Standard error	.06483	.09020	.08084	.04919
Slope	-.04229	.00114	.08986	.00631
Standard error	.02226	.03006	.02651	.00453
t-ratio	-1.90014	.03806	3.39014	1.39304
prob t	.08393	.97047	.00537	.17215
Correlation Coefficient	-.49711	.01269	.69944	.22616

[1]See Section 4 for discussion of regression equations and units.

Table C-32. ANOVA for **set elevation** with crews in BDU.

	Sum Sq	*DF*	*Mean Sq*
Crew	.02548	2	.61645
Error	.01274	35	.01761

Mean of Dependent Variable	.83298
Number of Observations	38
Total Sum of Squares	.64192
Residual Sum of Squares	.61645
Std. Dev. of Estimate	.13271
R-squared	.03969
Adjusted R-squared	-.01519
Degrees of Freedom (df)	35
Number of Ind Vars (K)	3
F(K-1, df)	.72325
Prob. Value of F	.49228

SET ELEVATION: MOPP4 - STANDARD

(Linear regression with 68 % confidence band)

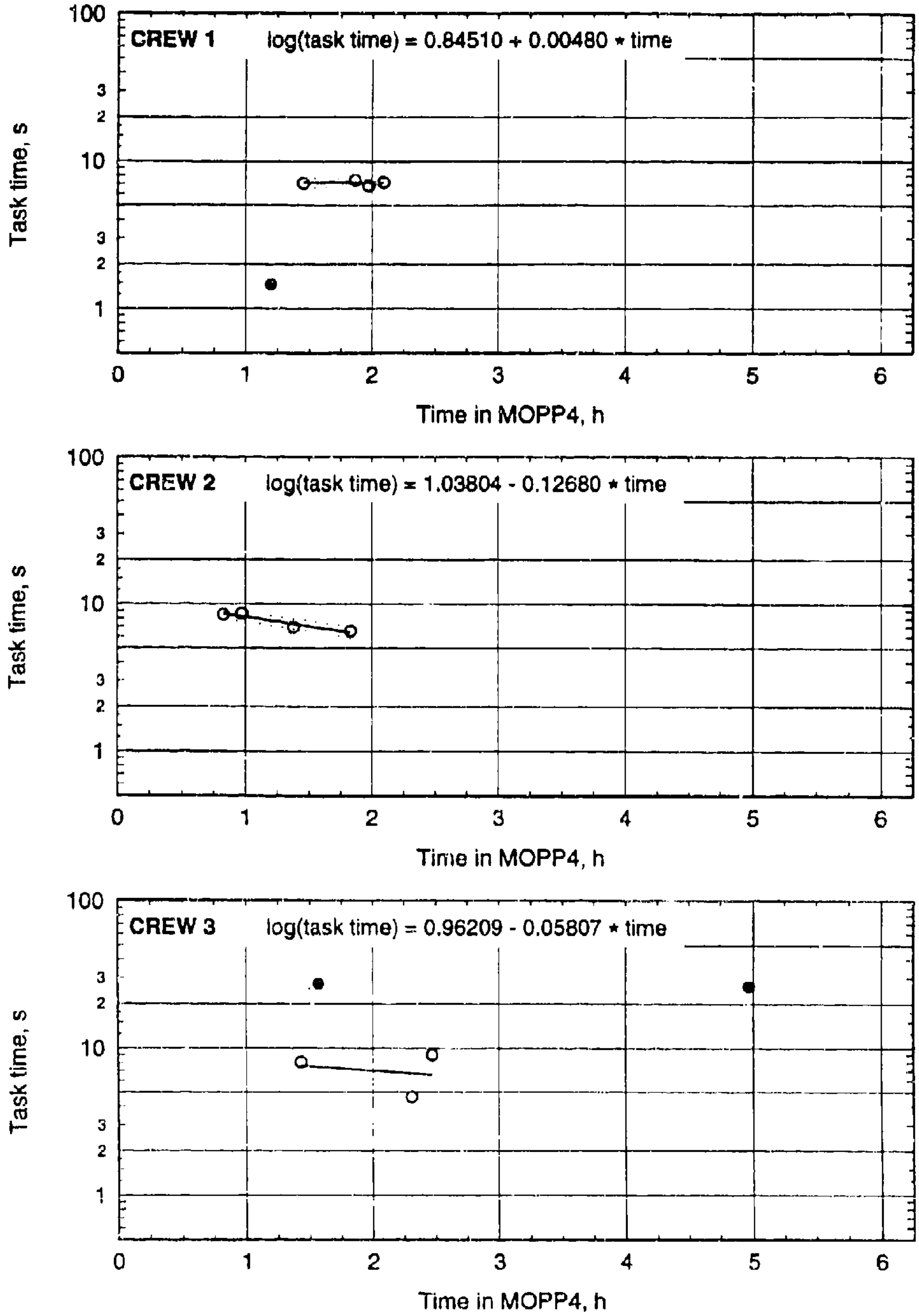


Figure C-33. Task times with regression lines for **set elevation** in MOPP4-S.

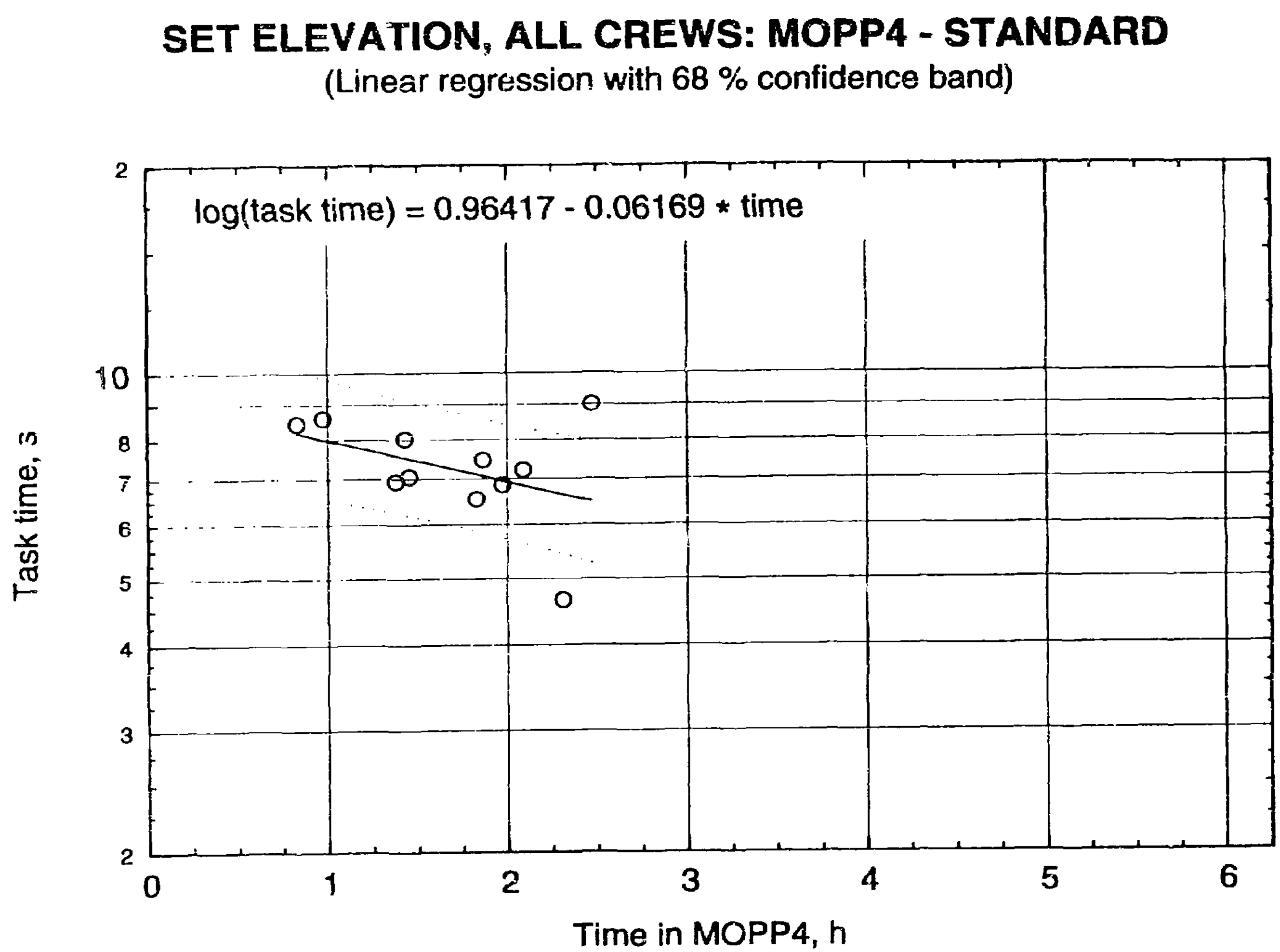


Figure C-34. Aggregate task time data with regression line for **set elevation** in MOPP4-S.

Table C-33. Statistical summary[1] for **set elevation** with crews in MOPP4-S.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	.85395	.87932	.84194	.85990
Number of Observations	4	4	3	11
Total Sum of Squares	.00071	.01070	.04697	.06100
Residual Sum of Squares	.00070	.00099	.04485	.05050
Std. Dev. of Estimate	.01872	.02226	.21178	.07491
R-squared	.00752	.90746	.04514	.17209
Adjusted R-squared	-.48872	.86119	-.90972	.08010
Degrees of Freedom (df)	2	2	1	9
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	.01515	19.61205	.04727	1.87077
Prob. Value of F	.91329	.04739	.86370	.20456
Constant	.84510	1.03804	.96209	.96417
Standard error	.07252	.03753	.56596	.07951
Slope	.00480	-.12680	-.05807	-.06169
Standard error	.03899	.02863	.26706	.04510
t-ratio	.12309	-4.42855	-.21743	-1.36776
prob t	.91329	.04739	.86370	.20456
Correlation Coefficient	.08671	-.95261	-.21246	-.41484

[1]See Section 4 for discussion of regression equations and units.

Table C-34. ANOVA for **set elevation** with crews in MOPP4-S.

	Sum Sq	*DF*	*Mean Sq*
Crew	.00262	2	.05838
Error	.00131	8	.00730

Mean of Dependent Variable	.85990
Number of Observations	11
Total Sum of Squares	.06100
Residual Sum of Squares	.05838
Std. Dev. of Estimate	.08543
R-squared	.04292
Adjusted R-squared	-.19636
Degrees of Freedom (df)	8
Number of Ind Vars (K)	3
F(K-1, df)	.17936
Prob. Value of F	.83907

SET ELEVATION: MOPP4 - ROTATING

(Linear regression with 68 % confidence band)

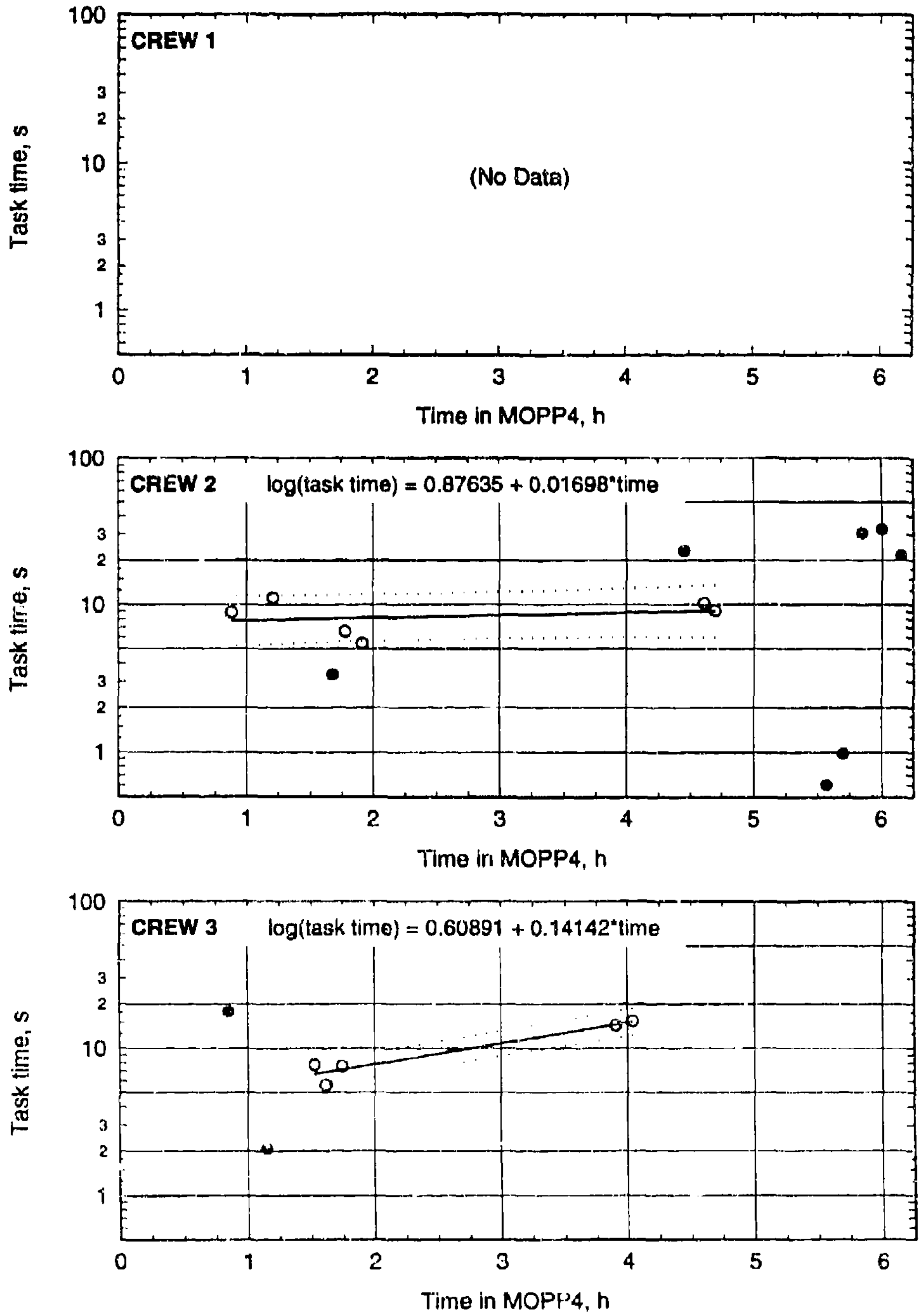


Figure C-35. Task times with regression lines for **set elevation** in MOPP4-R.

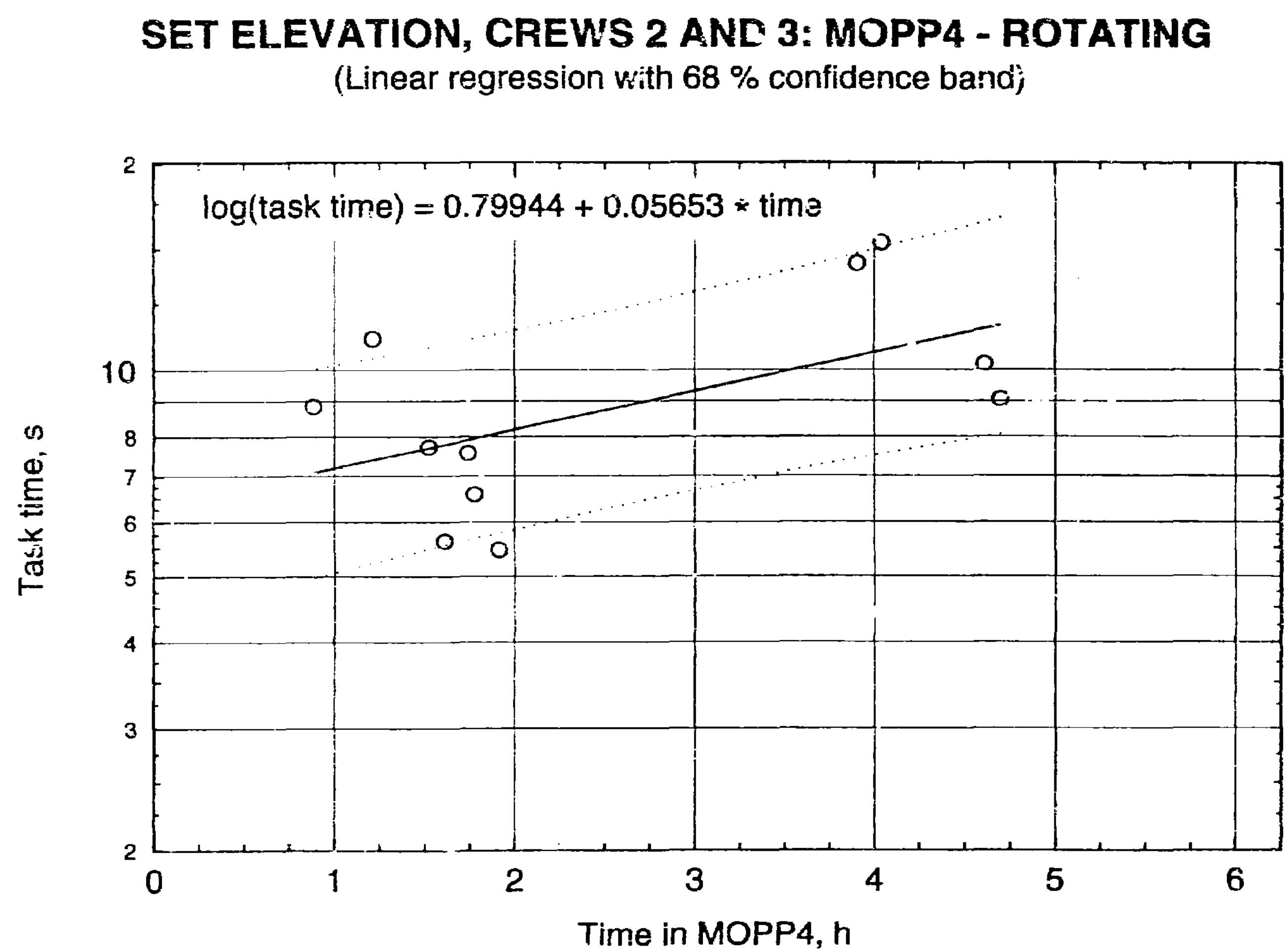


Figure C-36. Aggregate task time data with regression line for **set elevation** in MOPP4-R.

Table C-35. Statistical summary[1] for **set elevation** with crews in MOPP4-R.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	No Data	.91904	.97142	.94285
Number of Observations		6	5	11
Total Sum of Squares		.06961	.14491	.22200
Residual Sum of Squares		.06545	.01215	.15471
Std. Dev. of Estimate		.12792	.06364	.13111
R-squared		.05968	.91615	.30310
Adjusted R-squared		-.17541	.88819	.22567
Degrees of Freedom (df)		4	3	9
Number of Ind Vars (K)		2	2	2
F(K-1, df)		.25385	32.77618	3.91441
Prob. Value of F		.64086	.01058	.07925
Constant		.87635	.60891	.79944
Standard error		.09953	.06942	.08256
Slope		.01698	.14142	.05653
Standard error		.03369	.02470	.02857
t-ratio		.50384	5.72505	1.97849
prob t		.64086	.01058	.07925
Correlation Coefficient		.24429	.95715	.55055

[1]See Section 4 for discussion of regression equations and units.

Table C-36. ANOVA for **set elevation** with crews in MOPP4-R.

	Sum Sq	*DF*	*Mean Sq*
Crew	.00748	1	.21451
Error	.00748	9	.02383

Mean of Dependent Variable	.94285
Number of Observations	11
Total Sum of Squares	.22200
Residual Sum of Squares	.21451
Std. Dev. of Estimate	.15439
R-squared	.03370
Adjusted R-squared	-.07366
Degrees of Freedom (df)	9
Number of Ind Vars (K)	2
F(K-1, df)	.31391
Prob. Value of F	.58896

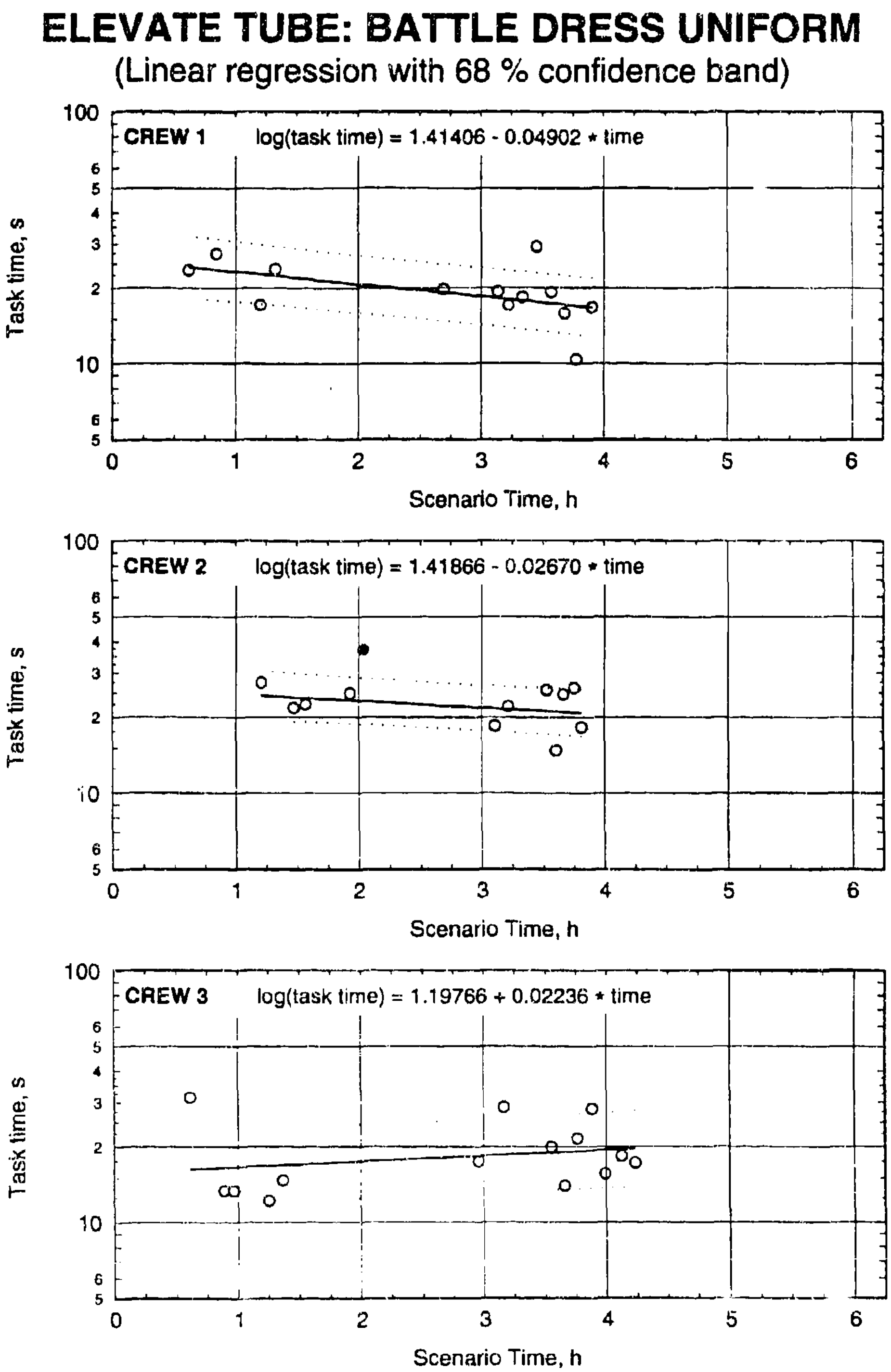


Figure C-37. Task times with regression lines for **elevate tube** in BDU.

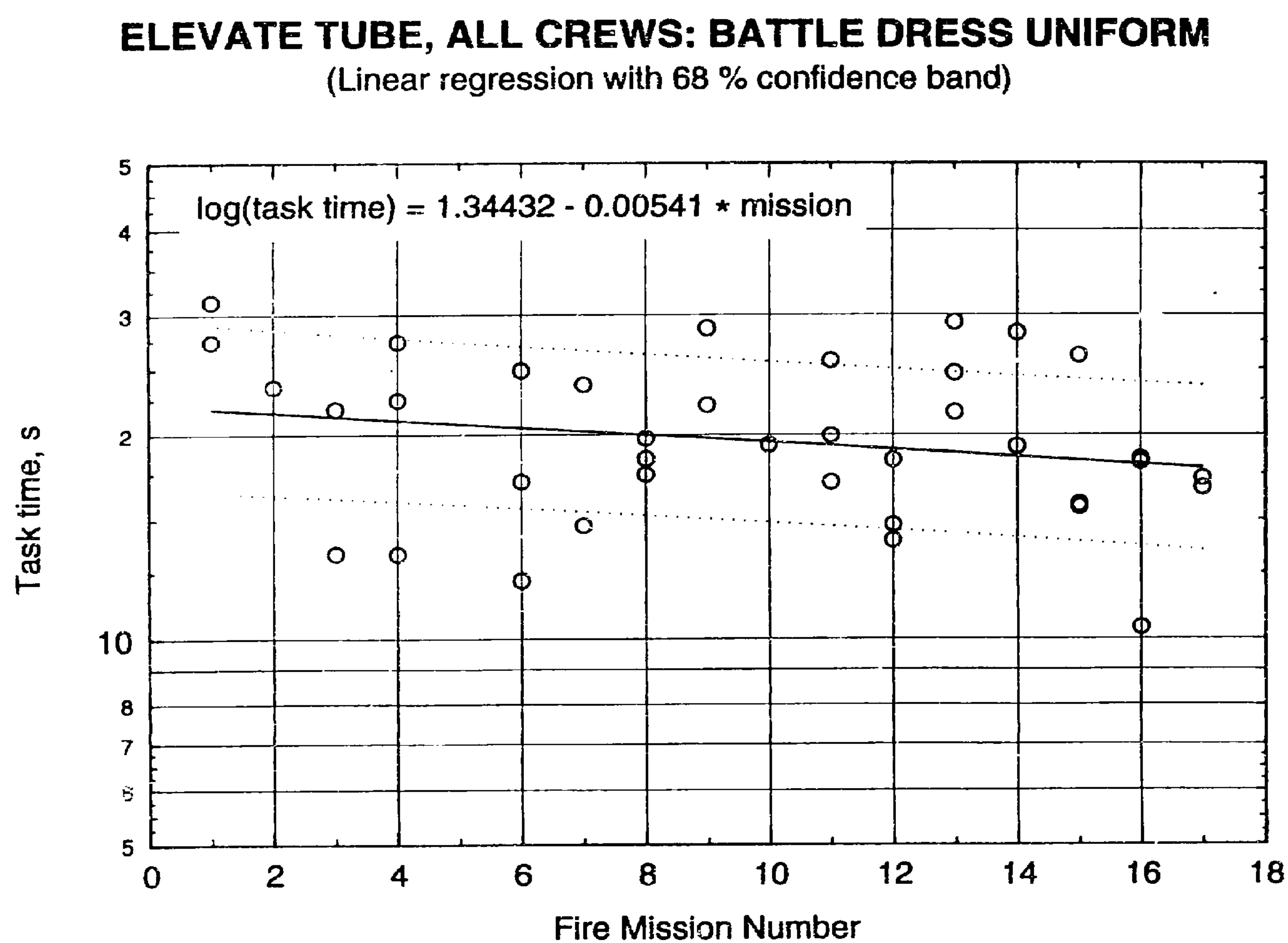


Figure C-38. Aggregate task time data with regression line for **elevate tube** in BDU.

Table C-37. Statistical summary[1] for **elevate tube** with crews in BDU.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	1.28307	1.34379	1.25902	1.29179
Number of Observations	13	11	14	38
Total Sum of Squares	.16130	.06732	.23194	.50633
Residual Sum of Squares	.11893	.05970	.21946	.48104
Std. Dev. of Estimate	.10398	.08145	.13523	.11560
R-squared	.26268	.11317	.05383	.04993
Adjusted R-squared	.19565	.01464	-.02502	.02354
Degrees of Freedom (df)	11	9	12	36
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	3.91881	1.14852	.68269	1.89207
Prob. Value of F	.07332	.31175	.42479	.17747
Constant	1.41406	1.41866	1.19766	1.34432
Standard error	.07218	.07405	.08259	.04255
Slope	-.04902	-.02670	.02236	-.00541
Standard error	.02476	.02492	.02706	.00393
t-ratio	-1.97960	-1.07169	.82625	-1.37553
prob t	.07332	.31175	.42479	.17747
Correlation Coefficient	-.51252	-.33641	.23201	-.22346

[1]See Section 4 for discussion of regression equations and units.

Table C-38. ANOVA for **elevate tube** with crews in BDU.

	Sum Sq	*DF*	*Mean Sq*
Crew	.04576	2	.46056
Error	.02288	35	.01316

Mean of Dependent Variable	1.29179
Number of Observations	38
Total Sum of Squares	.50633
Residual Sum of Squares	.46056
Std. Dev. of Estimate	.11471
R-squared	.09039
Adjusted R-squared	.03841
Degrees of Freedom (df)	35
Number of Ind Vars (K)	3
F(K-1, df)	1.73892
Prob. Value of F	19055

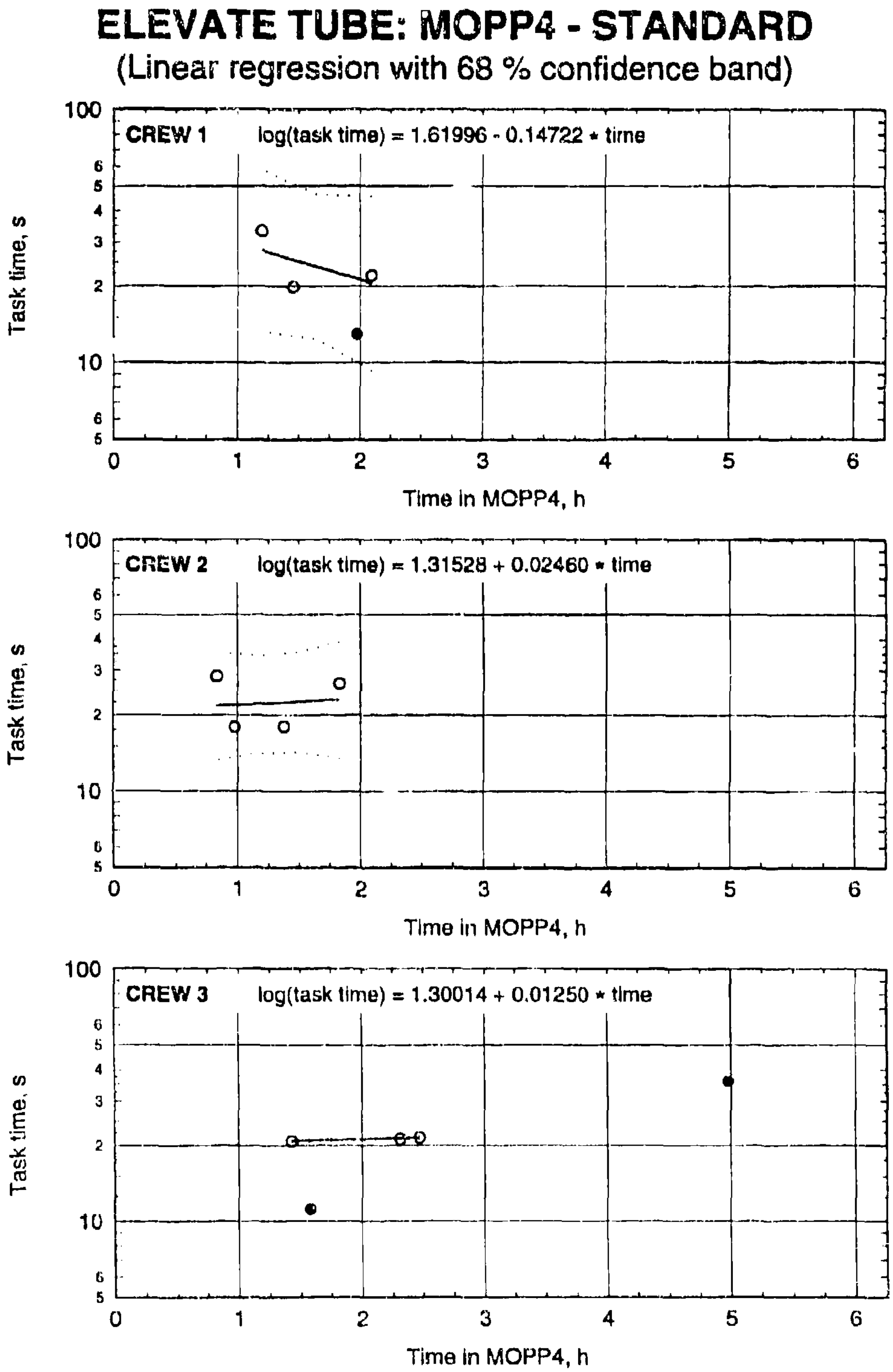


Figure C-39. Task times with regression lines for **elevate tube** in MOPP4-S.

ELEVATE TUBE, ALL CREWS: MOPP4 - STANDARD

(Linear regression with 68 % confidence band)

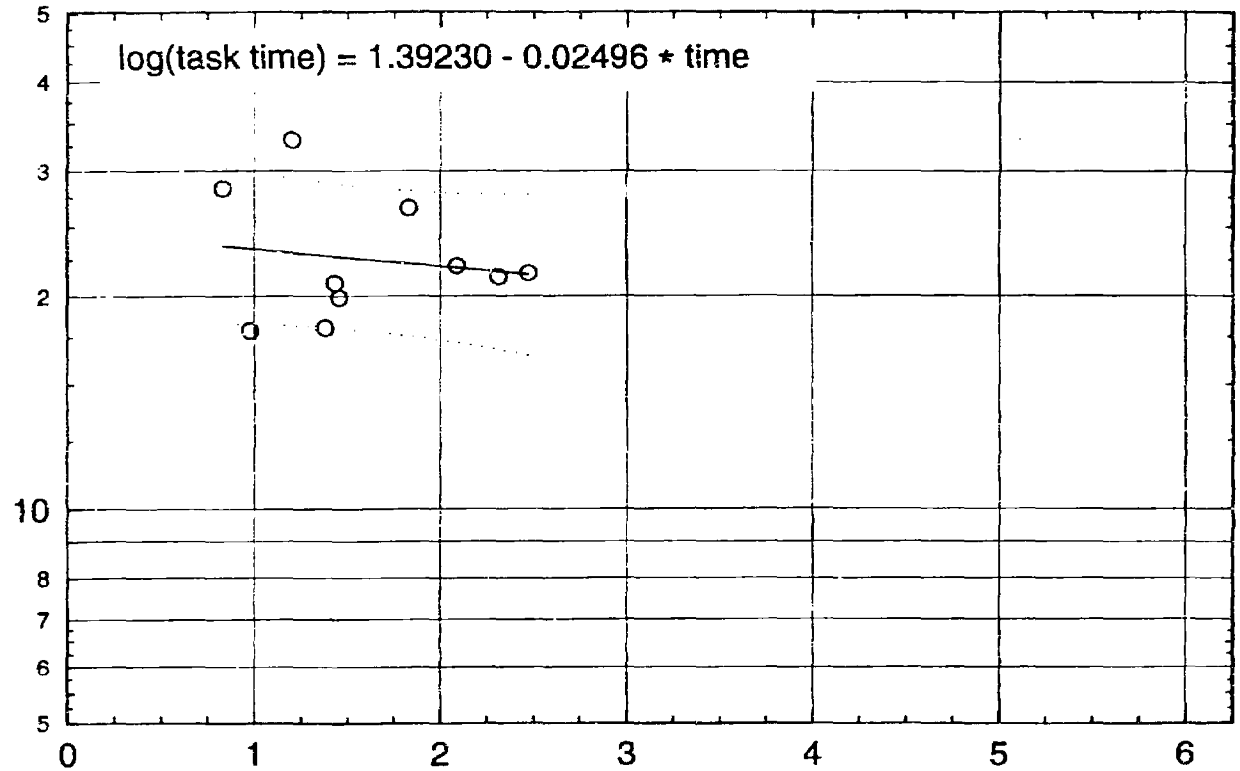


Figure C-40. Aggregate task time data with regression line for **elevate tube** in MOPP4-S.

Table C-39. Statistical summary[1] for **elevate tube** with crews in MOPP4-S.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	1.38722	1.34613	1.32602	1.35242
Number of Observations	3	4	3	10
Total Sum of Squares	.02753	.03456	.00010	.06808
Residual Sum of Squares	.01840	.03420	.00000	.06633
Std. Dev. of Estimate	.13566	.13076	.00220	.09106
R-squared	.33147	.01057	.95299	.02563
Adjusted R-squared	-.33706	-.48415	.90597	-.09617
Degrees of Freedom (df)	1	2	1	8
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	.49582	.02136	20.27036	.21039
Prob. Value of F	.60943	.89721	.13914	.65866
Constant	1.61996	1.31528	1.30014	1.39230
Standard error	.33968	.22097	.00589	.09157
Slope	-.14722	.02460	.01250	-.02496
Standard error	.20908	.16833	.00278	.05442
t-ratio	-.70415	.14615	4.50226	-.45869
prob t	.60943	.89721	.13914	.65866
Correlation Coefficient	-.57574	.10279	.97621	-.16008

[1]See Section 4 for discussion of regression equations and units.

Table C-40. ANOVA for **elevate tube** with crews in MOPP4-S.

	Sum Sq	*DF*	*Mean Sq*
Crew	.00588	2	.06220
Error	.00294	7	.00889

Mean of Dependent Variable	1.35242
Number of Observations	10
Total Sum of Squares	.06808
Residual Sum of Squares	.06220
Std. Dev. of Estimate	.09426
R-squared	.08639
Adjusted R-squared	-.17464
Degrees of Freedom (df)	7
Number of Ind Vars (K)	3
F(K-1, df)	.33096
Prob. Value of F	.72889

ELEVATE TUBE: MOPP4 - ROTATING

(Linear regression with 68 % confidence band)

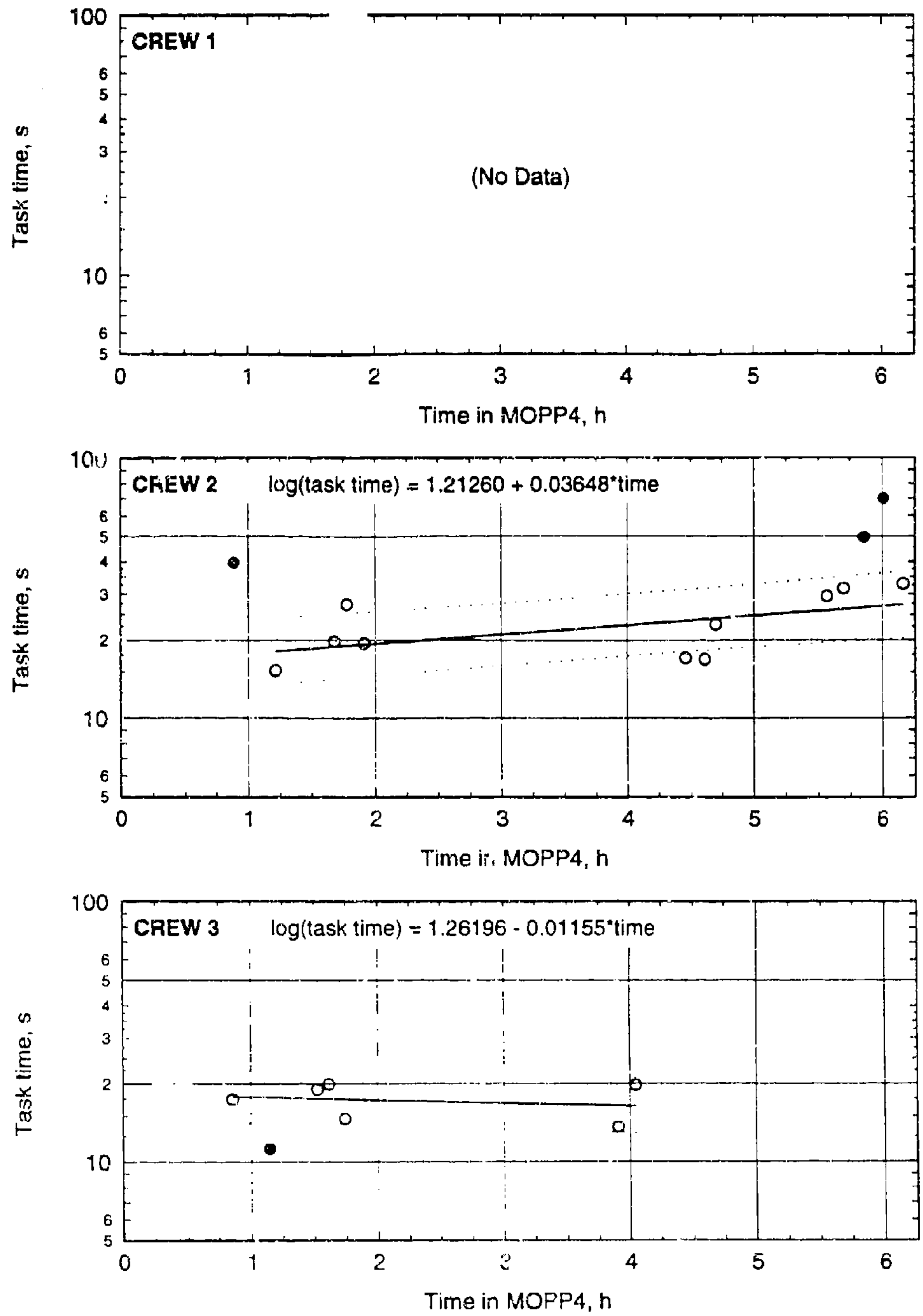


Figure C-41. Task times with regression lines for **elevate tube** in MOPP4-R.

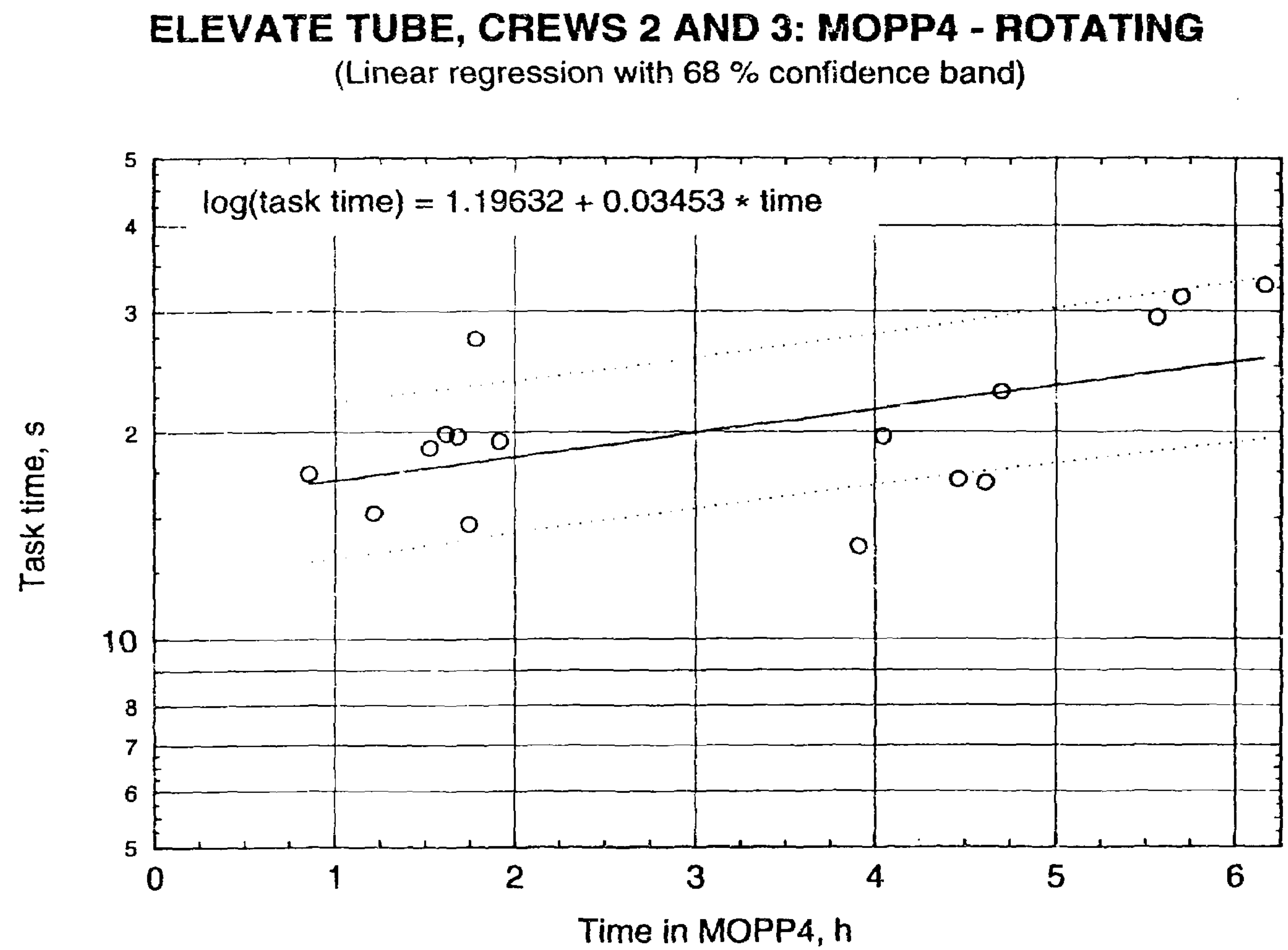


Figure C-42. Aggregate task time data with regression line for **elevate tube** in MOPP4-R.

Table C-41. Statistical summary[1] for **elevate tube** with crews in MOPP4-R.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	No Data	1.35045	1.23563	1.30739
Number of Observations		10	6	16
Total Sum of Squares		.13520	.02437	.20900
Residual Sum of Squares		.09122	.02316	.14873
Std. Dev. of Estimate		.10678	.07609	.10307
R-squared		.32533	.04976	.28840
Adjusted R-squared		.24099	-.18781	.23757
Degrees of Freedom (df)		8	4	14
Number of Ind Vars (K)		2	2	2
F(K-1, df)		3.85759	.20944	5.67387
Prob. Value of F		.08512	.67096	.03195
Constant		1.21260	1.26196	1.19632
Standard error		.07788	.06539	.05328
Slope		.03648	-.01155	.03453
Standard error		.01857	.02523	.01449
t-ratio		1.96407	-.45765	2.38199
prob t		.08512	.67096	.03195
Correlation Coefficient		.57037	-.22306	.53703

[1]See Section 4 for discussion of regression equations and units.

Table C-42. ANOVA for **elevate tube** with crews in MOPP4-R.

	Sum Sq	*DF*	*Mean Sq*
Crew	.04944	1	.15957
Error	.04944	14	.01140

Mean of Dependent Variable	1.30739
Number of Observations	16
Total Sum of Squares	.20900
Residual Sum of Squares	.15957
Std. Dev. of Estimate	.10676
R-squared	.23653
Adjusted R-squared	.18200
Degrees of Freedom (df)	14
Number of Ind Vars (K)	2
F(K-1, df)	4.33742
Prob. Value of F	.05610

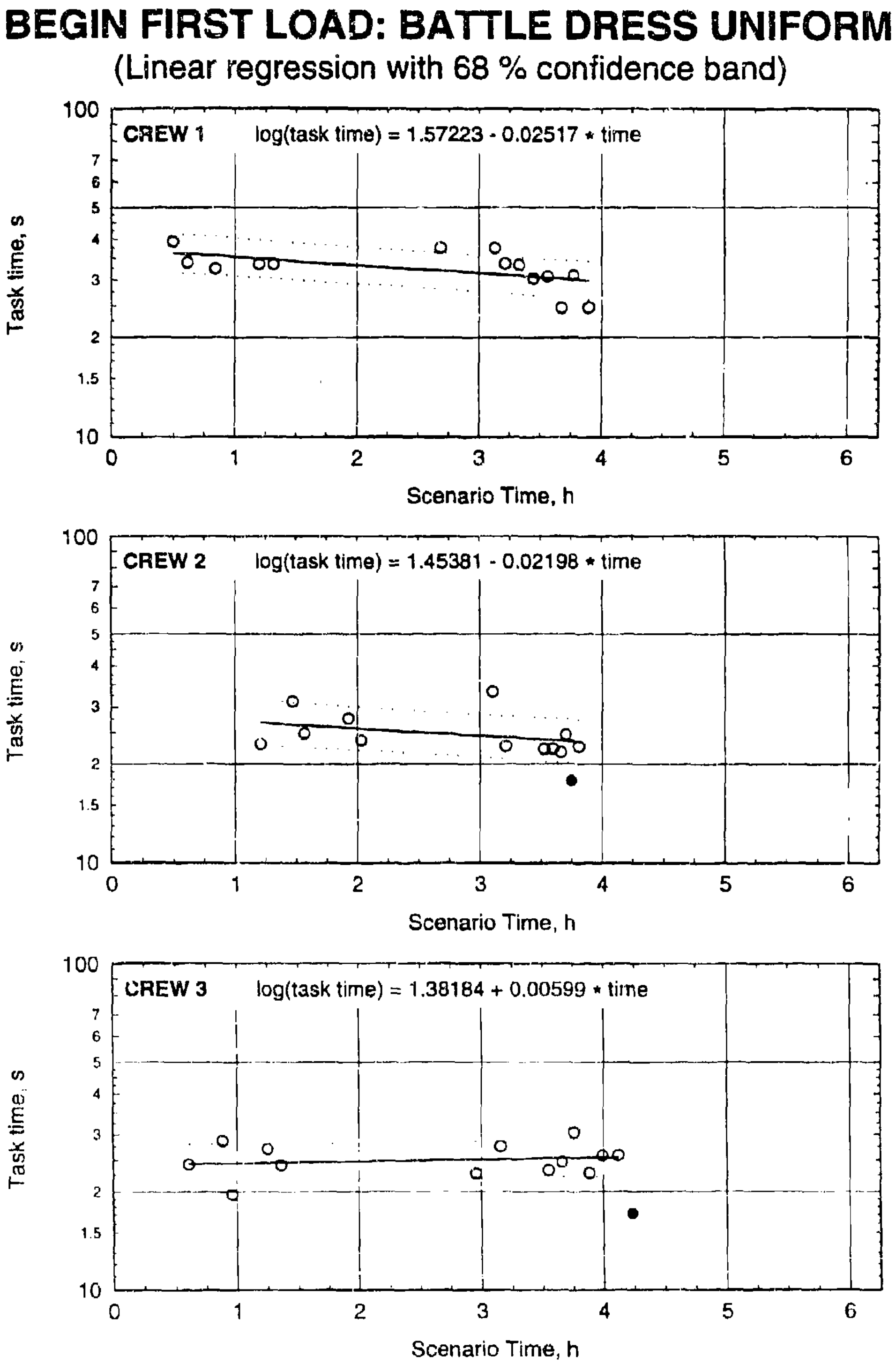


Figure C-43. Task times with regression lines for **begin first load** in BDU.

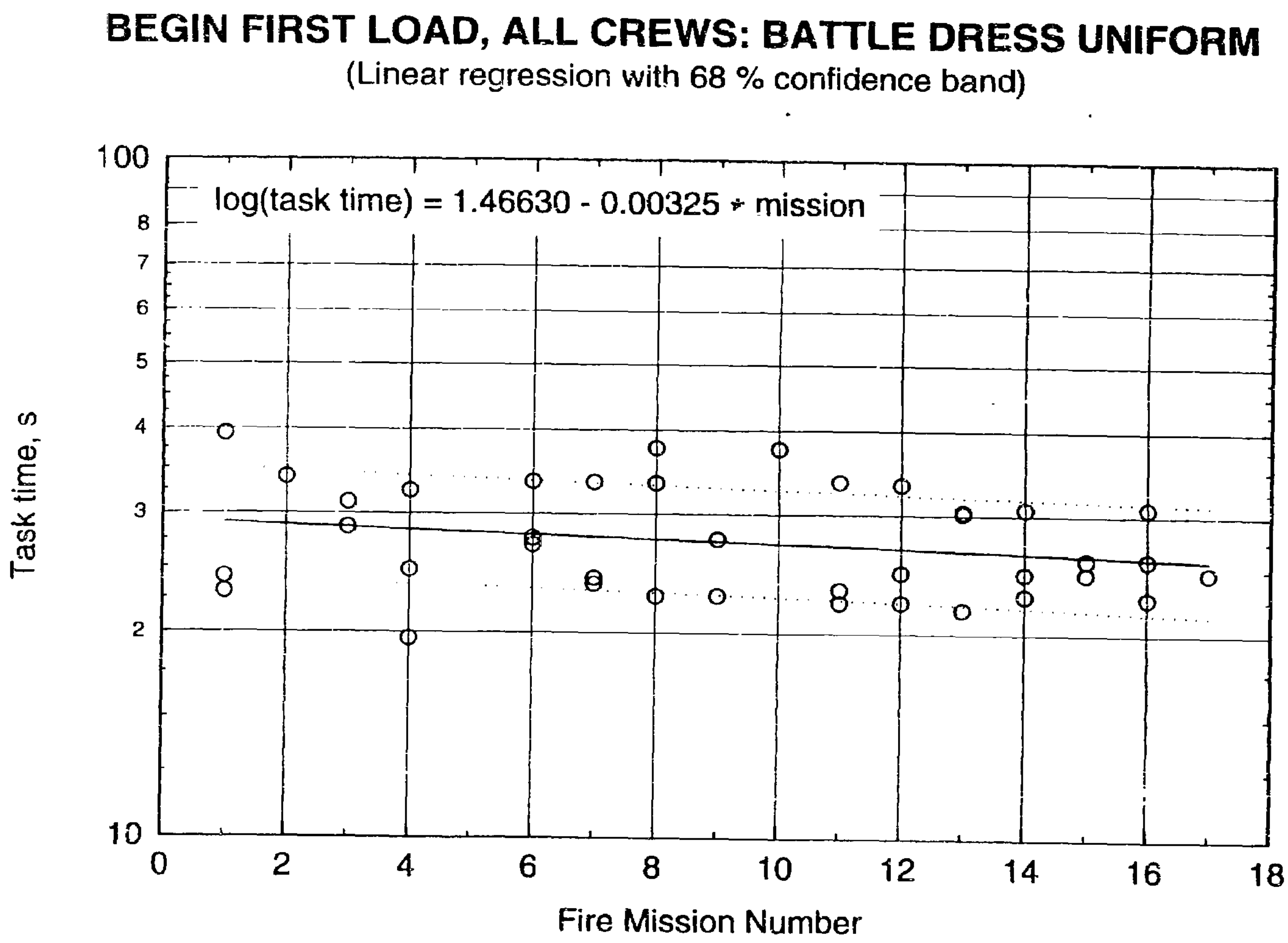


Figure C-44. Aggregate task time data with regression line for **begin first load** in BDU.

Table C-43. Statistical summary[1] for **begin first load** with crews in BDU.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	1.50904	1.39373	1.39756	1.43640
Number of Observations	14	12	13	39
Total Sum of Squares	.04656	.04057	.02998	.23243
Residual Sum of Squares	.03263	.03519	.02917	.22321
Std. Dev. of Estimate	.05215	.05932	.05149	.07767
R-squared	.29915	.13255	.02709	.03968
Adjusted R-squared	.24074	.04580	-.06136	.01373
Degrees of Freedom (df)	12	10	11	37
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	5.12198	1.52798	.30628	1.52888
Prob. Value of F	.04296	.24466	.59104	.22407
Constant	1.57223	1.45381	1.38184	1.46630
Standard error	.03121	.05153	.03180	.02719
Slope	-.02517	-.02198	.00599	-.00325
Standard error	.01112	.01778	.01083	.00263
t-ratio	-2.26318	-1.23611	.55343	-1.23648
prob t	.04296	.24466	.59104	.22407
Correlation Coefficient	-.54694	-.36407	.16459	-.19920

[1]See Section 4 for discussion of regression equations and units.

Table C-44. ANOVA for **begin first load** with crews in BDU.

	Sum Sq	*DF*	*Mean Sq*
Crew	.11532	2	.11711
Error	.05766	36	.00325

Mean of Dependent Variable	1.43640
Number of Observations	39
Total Sum of Squares	.23243
Residual Sum of Squares	.11711
Std. Dev. of Estimate	.05704
R-squared	.49615
Adjusted R-squared	.46816
Degrees of Freedom (df)	36
Number of Ind Vars (K)	3
F(K-1, df)	17.72483
Prob. Value of F	.00000

BEGIN FIRST LOAD: MOPP4 - STANDARD

(Linear regression with 68 % confidence band)

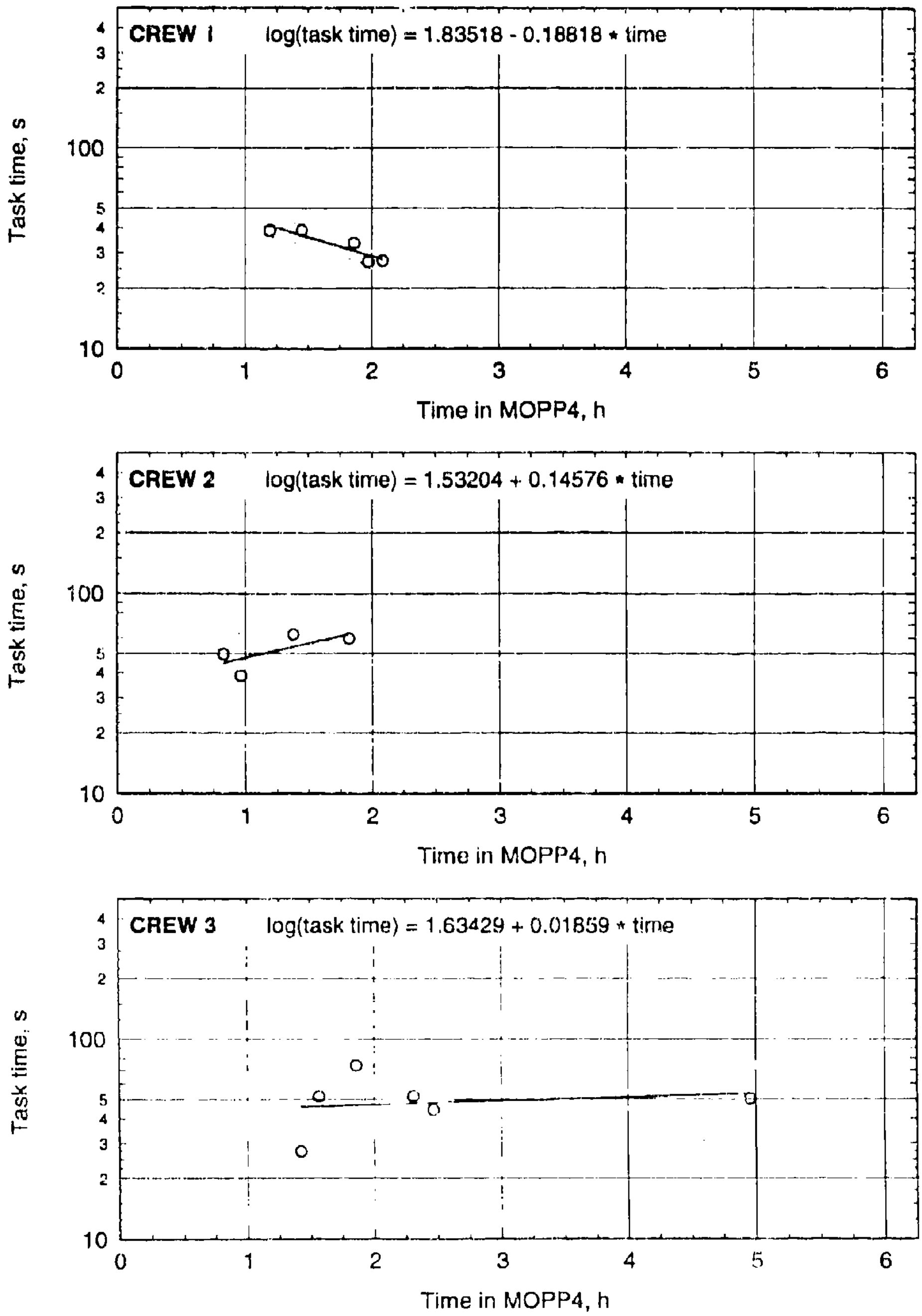


Figure C-45. Task times with regression lines for **begin first load** in MOPP4-S.

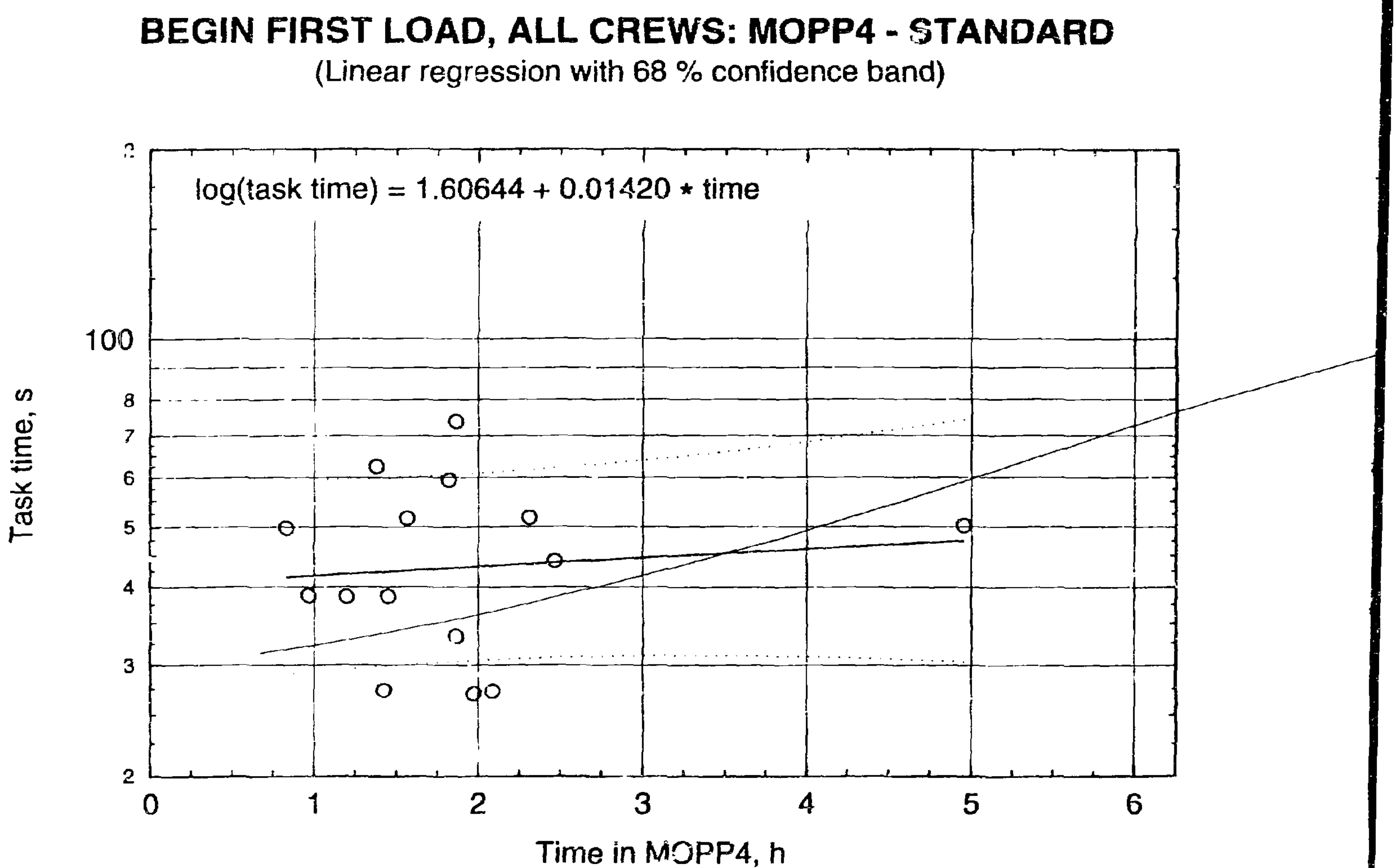


Figure C-46. Aggregate task time data with regression line for **begin first load** in MOPP4-S.

Table C-45. Statistical summary[1] for **begin first load** with crews in MOPP4-S.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	1.51279	1.71386	1.67945	1.63307
Number of Observations	5	4	6	15
Total Sum of Squares	.02371	.02629	.09806	.25941
Residual Sum of Squares	.00372	.01358	.09513	.25675
Std. Dev. of Estimate	.03520	.08239	.15421	.14053
R-squared	.84327	.48355	.02989	.01026
Adjusted R-squared	.79103	.22532	-.21264	-.06587
Degrees of Freedom (df)	3	2	4	13
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	16.14177	1.87257	.12322	.13478
Prob. Value of F	.02769	.30462	.74327	.71943
Constant	1.83518	1.53204	1.63429	1.60644
Standard error	.08177	.13910	.14323	.08112
Slope	-.18818	.14576	.01859	.01420
Standard error	.04684	.10652	.05295	.03868
t-ratio	-4.01768	1.36842	.35103	.36713
prob t	.02769	.30462	.74327	.71943
Correlation Coefficient	-.91830	.69538	.17287	.10130

[1]See Section 4 for discussion of regression equations and units.

Table C-46. ANOVA for **begin first load** with crews in MOPP4-S.

	Sum Sq	*DF*	*Mean Sq*
Crew	.11135	2	.14806
Error	.05568	12	.01234

Mean of Dependent Variable	1.63307
Number of Observations	15
Total Sum of Squares	.25941
Residual Sum of Squares	.14806
Std. Dev. of Estimate	.11108
R-squared	.42925
Adjusted R-squared	.33412
Degrees of Freedom (df)	12
Number of Ind Vars (K)	3
F(K-1, df)	4.51243
Prob. Value of F	.03457

BEGIN FIRST LOAD: MOPP4 - ROTATING

(Linear regression with 68 % confidence band)

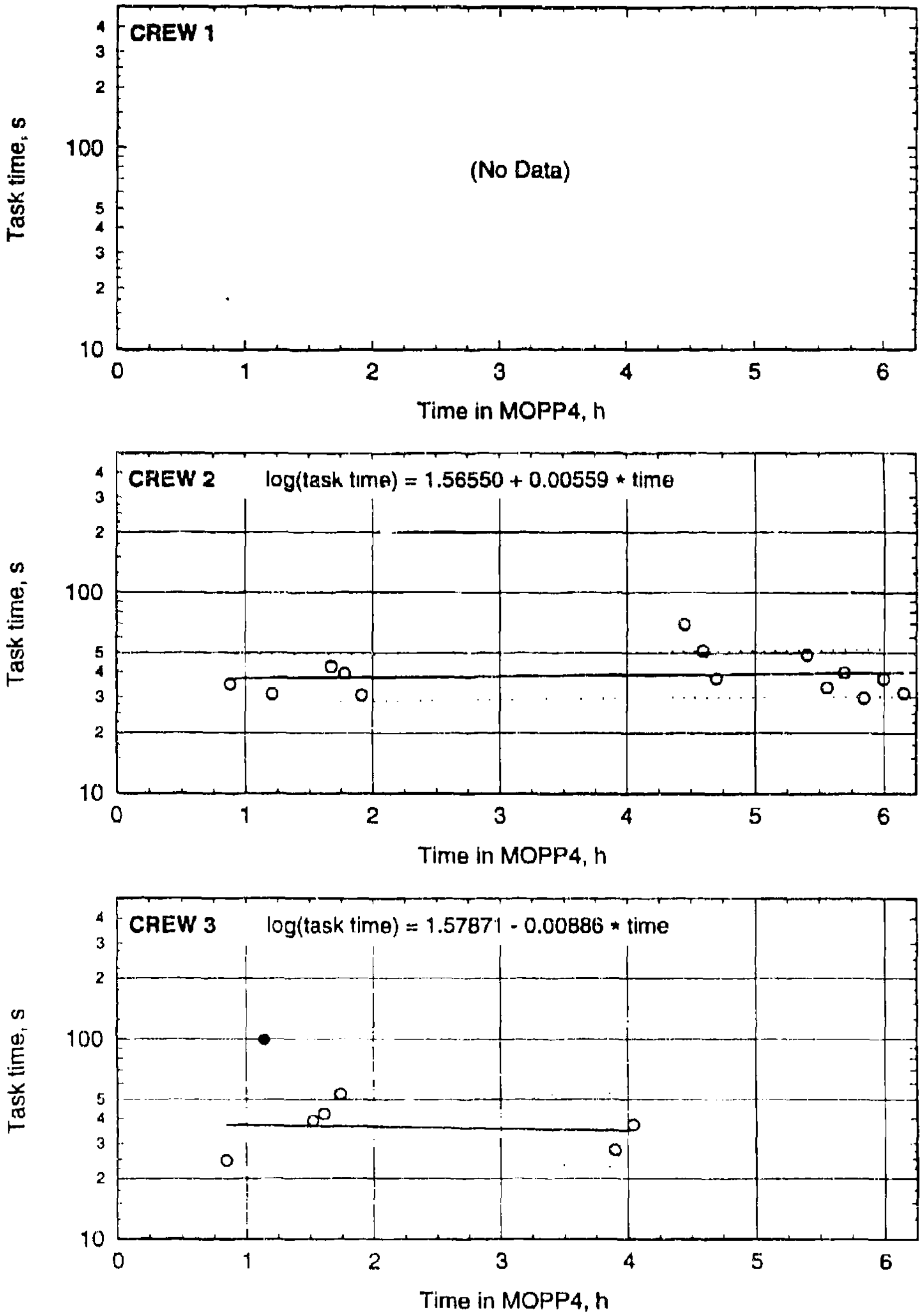


Figure C-47. Task times with regression lines for **begin first load** in MOPP4-R.

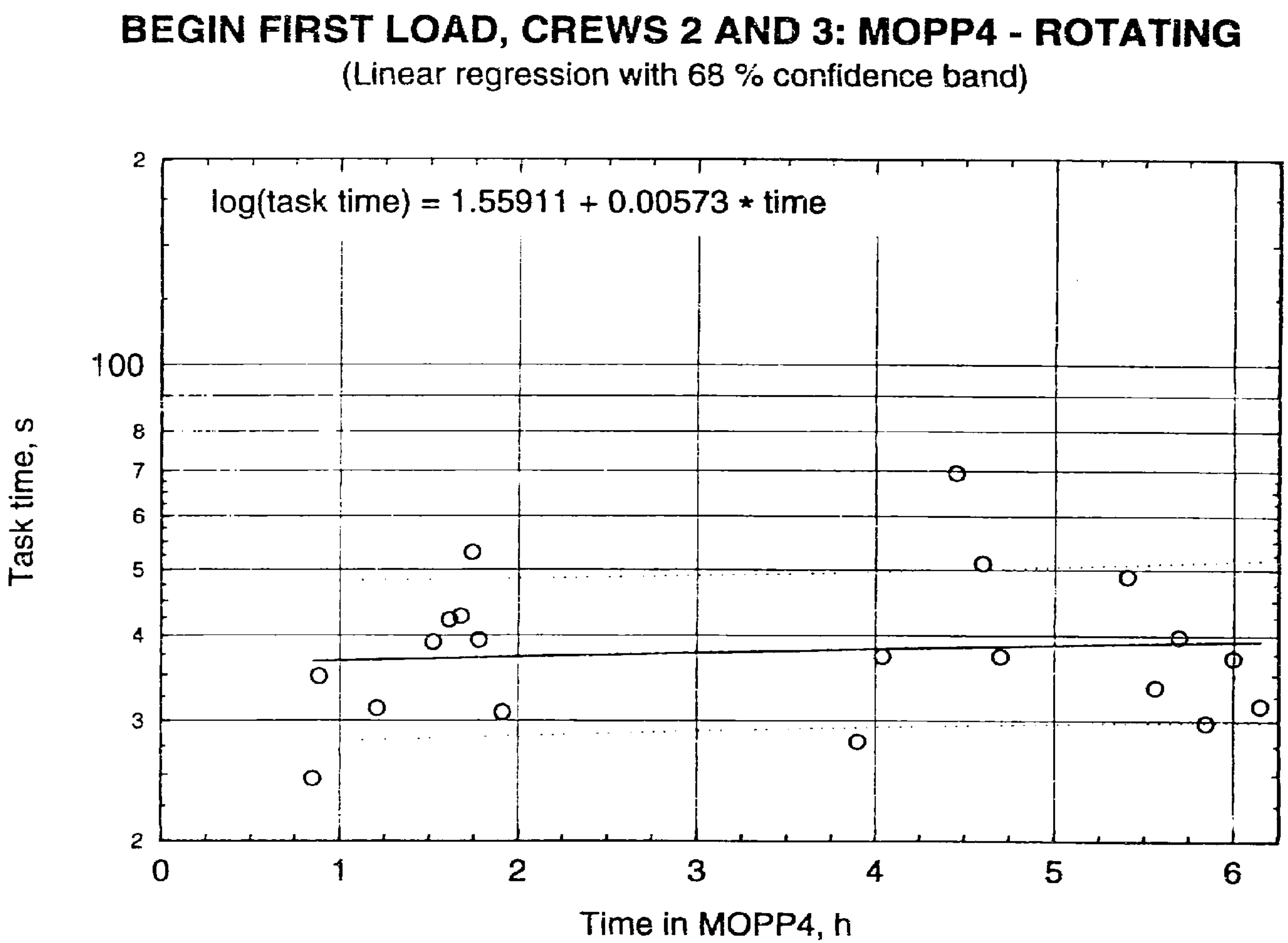


Figure C-48. Aggregate task time data with regression line for **begin first load** in MOPP4-R.

Table C-47. Statistical summary[1] for **begin first load** with crews in MOPP4-R.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	No Data	1.58779	1.55855	1.57902
Number of Observations		14	6	20
Total Sum of Squares		.13727	.07368	.21454
Residual Sum of Squares		.13563	.07297	.21211
Std. Dev. of Estimate		.10631	.13506	.10855
R-squared		.01196	.00968	.01131
Adjusted R-squared		-.07038	-.23790	-.04361
Degrees of Freedom (df)		12	4	18
Number of Ind Vars (K)		2	2	2
F(K-1, df)		.14527	.03909	.20598
Prob. Value of F		.70976	.85292	.65536
Constant		1.56550	1.57871	1.55911
Standard error		.06504	.11592	.05013
Slope		.00559	-.00886	.00575
Standard error		.01466	.04481	.01262
t-ratio		.38114	-.19771	.45385
prob t		.70976	.85292	.65536
Correlation Coefficient		.10937	-.09837	.10637

[1]See Section 4 for discussion of regression equations and units.

Table C-48. ANOVA for **begin first load** with crews in MOPP4-R.

	Sum Sq	*DF*	*Mean Sq*
Crew	.00359	1	.21095
Error	.00359	18	.01172

Mean of Dependent Variable	1.57902
Number of Observations	20
Total Sum of Squares	.21454
Residual Sum of Squares	.21095
Std. Dev. of Estimate	.10826
R-squared	.01674
Adjusted R-squared	-.03788
Degrees of Freedom (df)	18
Number of Ind Vars (K)	2
F(K-1, df)	.30648
Prob. Value of F	.58666

LOAD PROJECTILE: BATTLE DRESS UNIFO. .M

(Linear regression with 68 % confidence band)

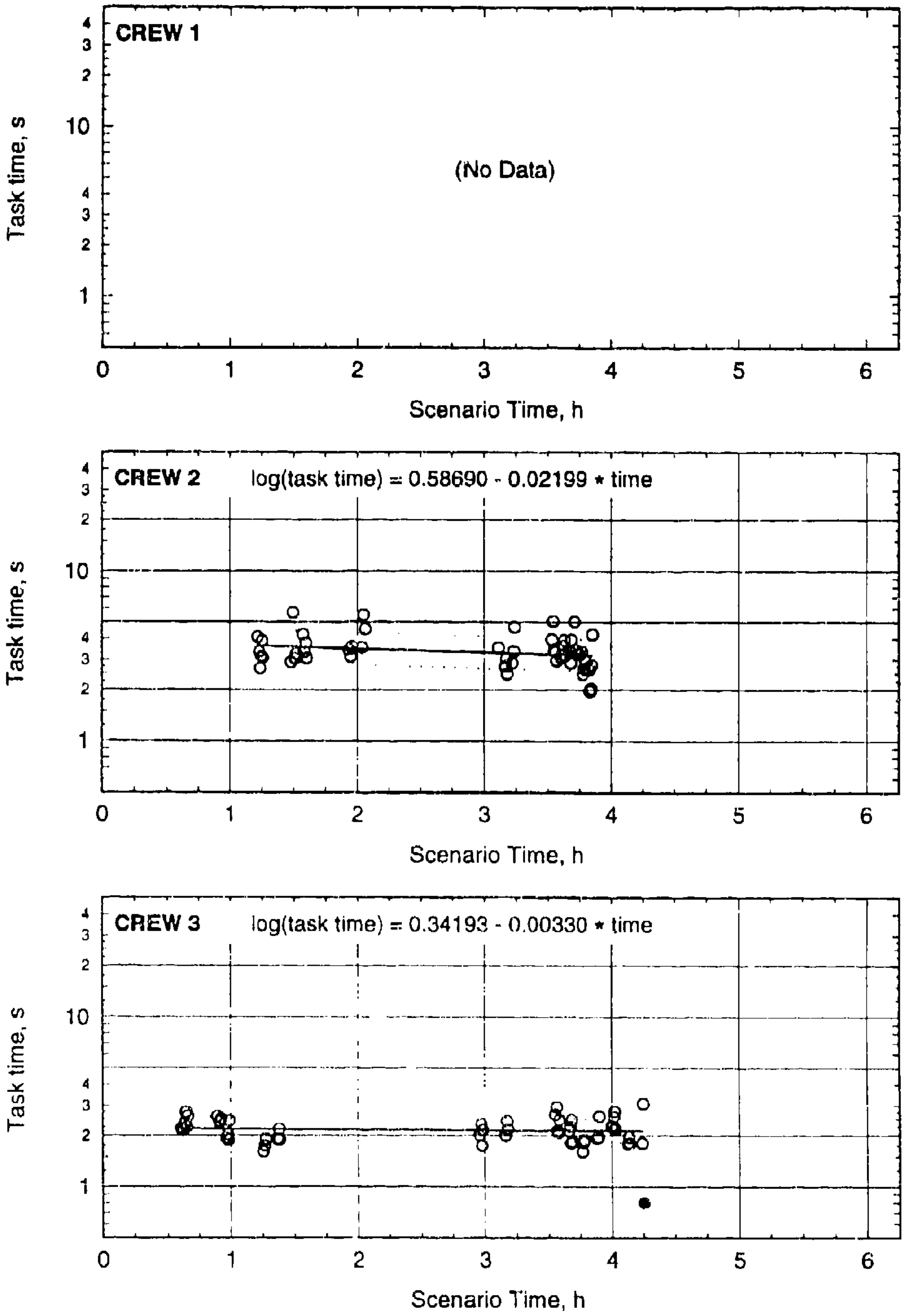


Figure C-49. Task times with regression lines for **load projectile** in BDU.

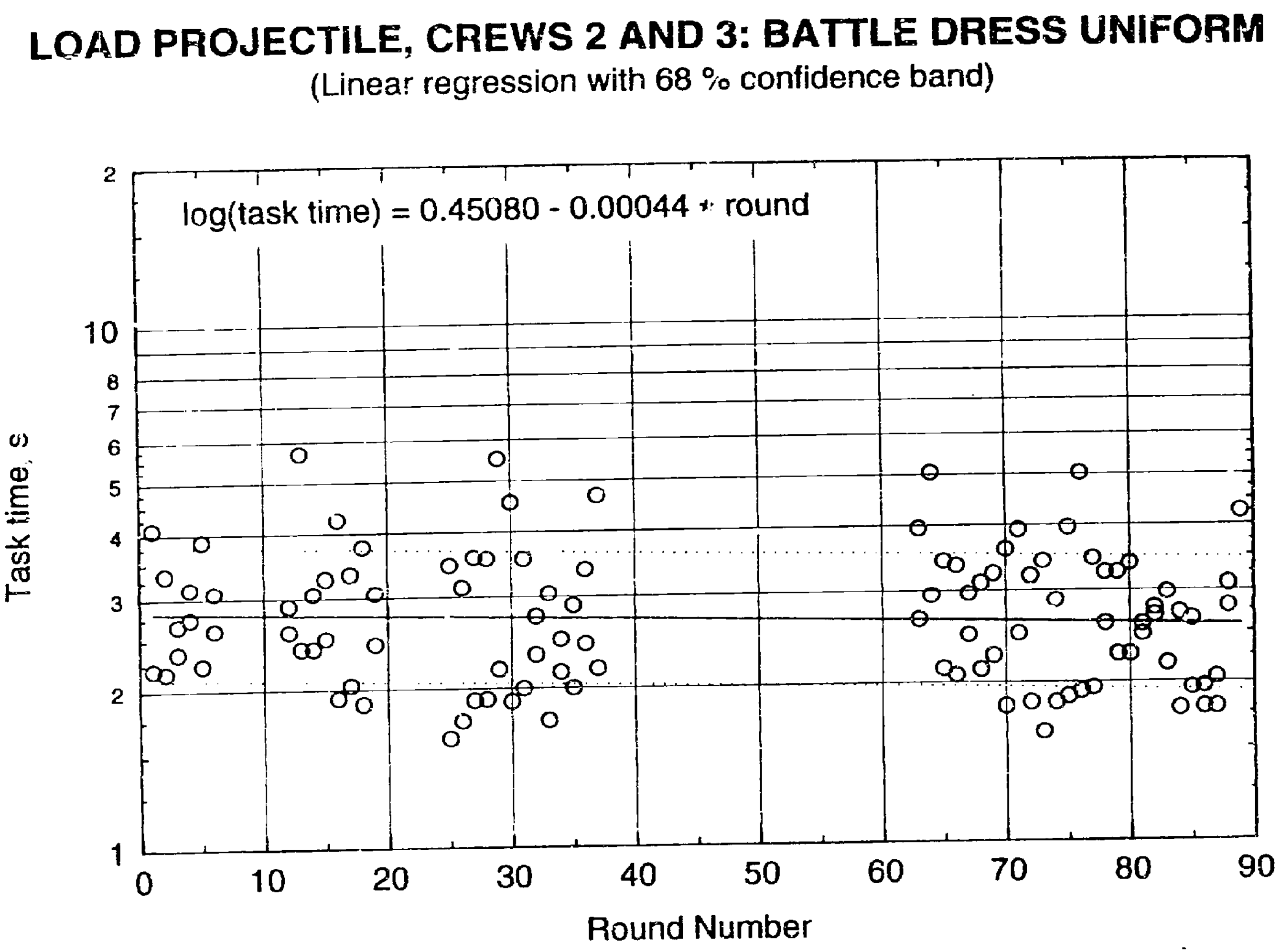


Figure C-50. Aggregate task time data with regression line for **load projectile** in BDU.

Table C-49. Statistical summary[1] for **load projectile** with crews in BDU.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	No Data	.52419	.33315	.42957
Number of Observations		54	53	107
Total Sum of Squares		.47078	.23809	1.68493
Residual Sum of Squares		.44452	.23702	1.66664
Std. Dev. of Estimate		.09246	.06817	.12599
R-squared		.05578	.00448	.01085
Adjusted R-squared		.03762	-.01504	.00143
Degrees of Freedom (df)		52	51	105
Number of Ind Vars (K)		2	2	2
F(K-1, df)		3.07168	.22953	1.15170
Prob. Value of F		.08556	.63392	.28565
Constant		.58690	.34193	.45080
Standard error		.03793	.02055	.02323
Slope		-.02199	-.00330	-.00044
Standard error		.01254	.00688	.00041
t-ratio		-1.75262	-.47910	-1.07317
prob t		.08556	.63392	.28565
Correlation Coefficient		-.23617	-.06694	-.10416

[1]See Section 4 for discussion of regression equations and units.

Table C-50. ANOVA for **load projectile** with crews in BDU.

	Sum Sq	*DF*	*Mean Sq*
Crew	.97605	1	.70887
Error	.97605	105	.00675

Mean of Dependent Variable	.42957
Number of Observations	107
Total Sum of Squares	1.68493
Residual Sum of Squares	.70887
Std. Dev. of Estimate	.08217
R-squared	.57929
Adjusted R-squared	.57528
Degrees of Freedom (df)	105
Number of Ind Vars (K)	2
F(K-1, df)	144.57560
Prob. Value of F	.00000

LOAD PROJECTILE: MOPP4 - STANDARD

(Linear regression with 68 % confidence band)

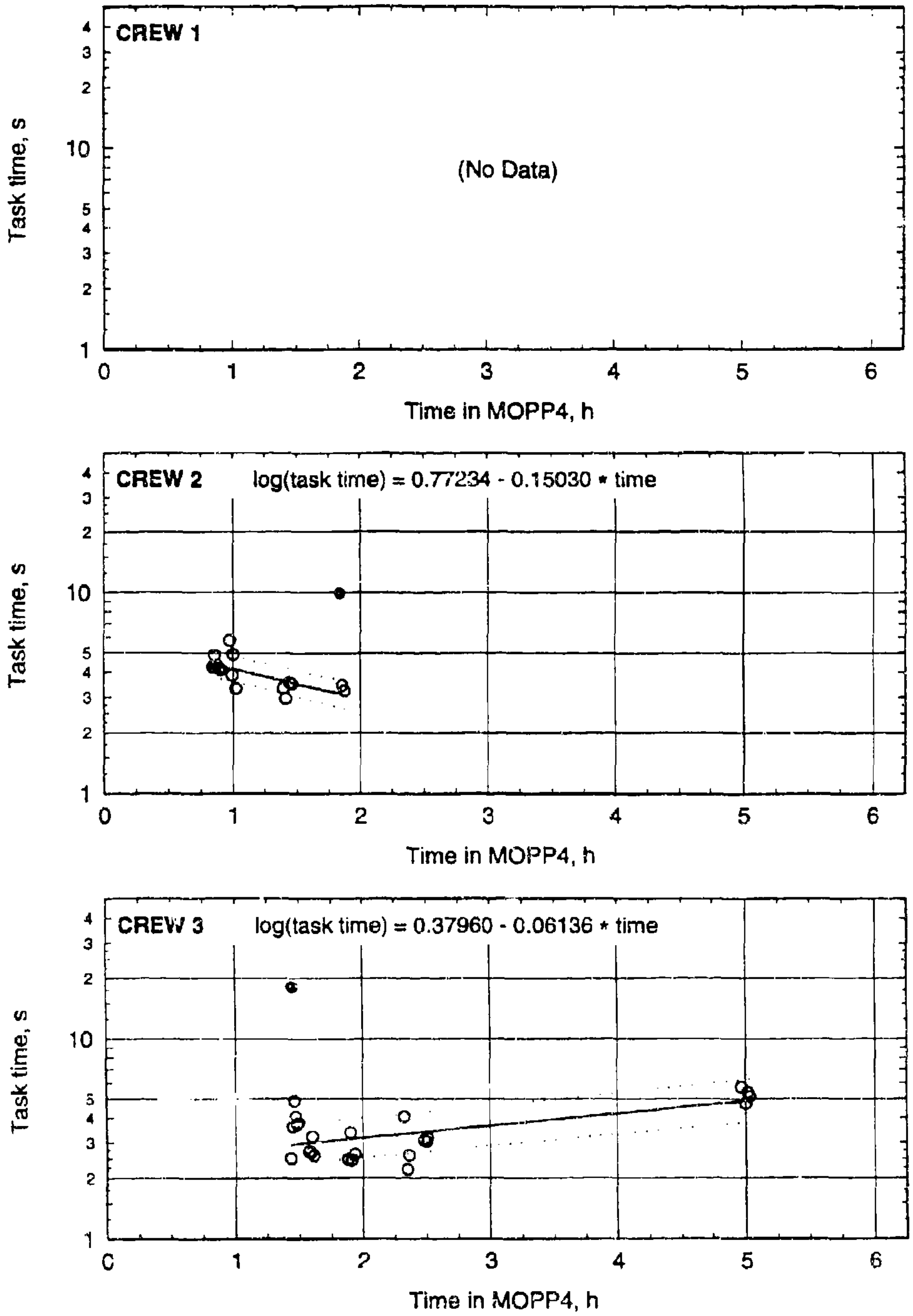


Figure C-51. Task times with regression lines for **load projectile** in MOPP4-S.

LOAD PROJECTILE, CREWS 2 AND 3: MOPP4 - STANDARD

(Linear regression with 68 % confidence band)

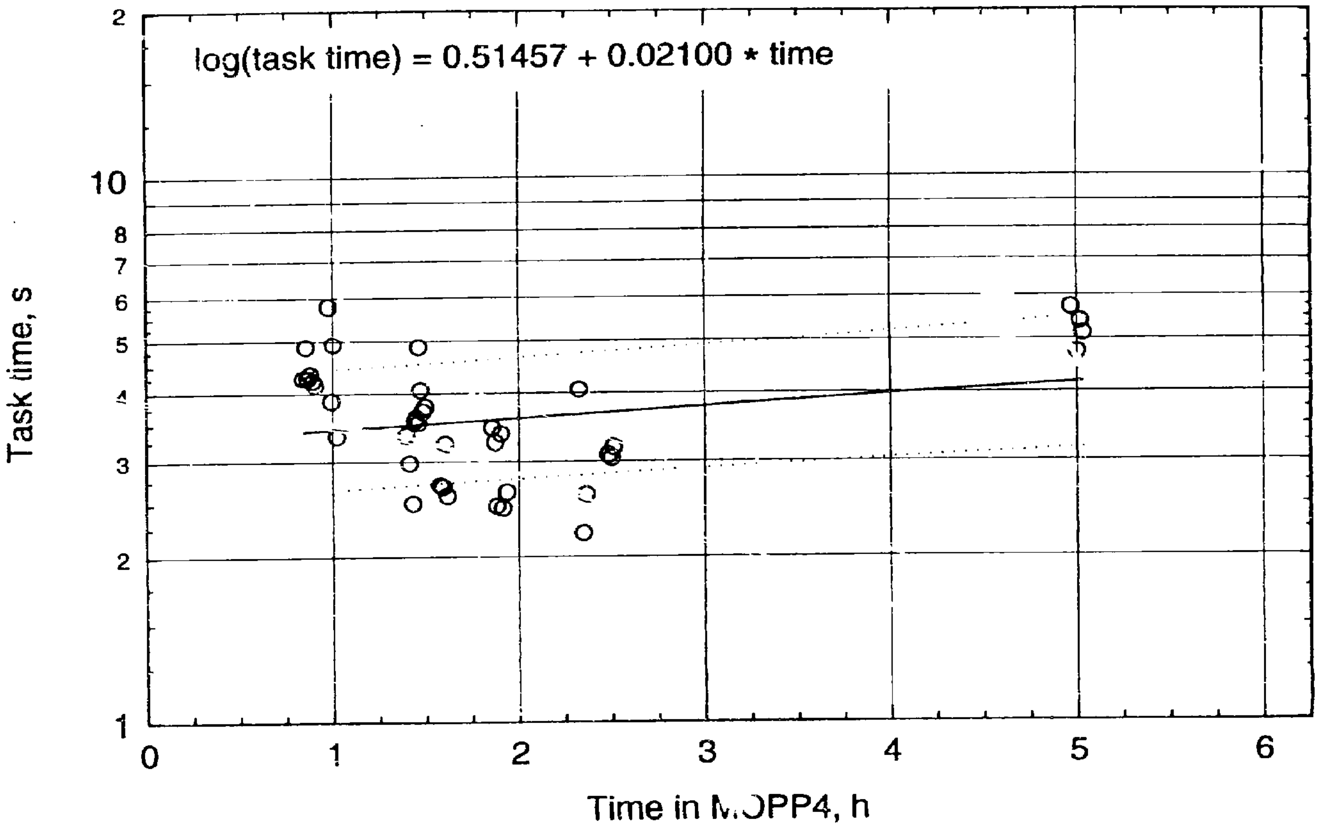


Figure C-52. Aggregate task time data with regression line for **load projectile** in MOPP4-S.

Table C-51. Statistical summary[1] for **load projectile** with crews in MOPP4-S.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	No Data	.59687	.52624	.55449
Number of Observations		16	24	40
Total Sum of Squares		.09087	.33831	.47707
Residual Sum of Squares		.04833	.20281	.45404
Std. Dev. of Estimate		.05876	.09601	.10931
R-squared		.46808	.40053	.04827
Adjusted R-squared		.43009	.37329	.02323
Degrees of Freedom (df)		14	22	38
Number of Ind Vars (K)		2	2	2
F(K-1, df)		12.31993	14.69930	1.92735
Prob. Value of F		.00347	.00090	.17313
Constant		.77234	.37960	.51457
Standard error		.05210	.04298	.03355
Slope		-.15030	.06136	.02100
Standard error		.04282	.01600	.01513
t-ratio		-3.50998	3.83397	1.38829
prob t		.00347	.00090	.17313
Correlation Coefficient		-.68417	.63288	.21971

[1]See Section 4 for discussion of regression equations and units.

Table C-52. ANOVA for **load projectile** with crews in MOPP4-S.

	Sum Sq	*DF*	*Mean Sq*
Crew	.04788	1	.42918
Error	.04788	38	.01129

Mean of Dependent Variable	.55449
Number of Observations	40
Total Sum of Squares	.47707
Residual Sum of Squares	.42918
Std. Dev. of Estimate	.10627
R-squared	.10037
Adjusted R-squared	.07670
Degrees of Freedom (df)	38
Number of Ind Vars (K)	2
F(K-1, df)	4.23975
Prob. Value of F	.04639

LOAD PROJECTILE: MOPP4 - ROTATING

(Linear regression with 68 % confidence band)

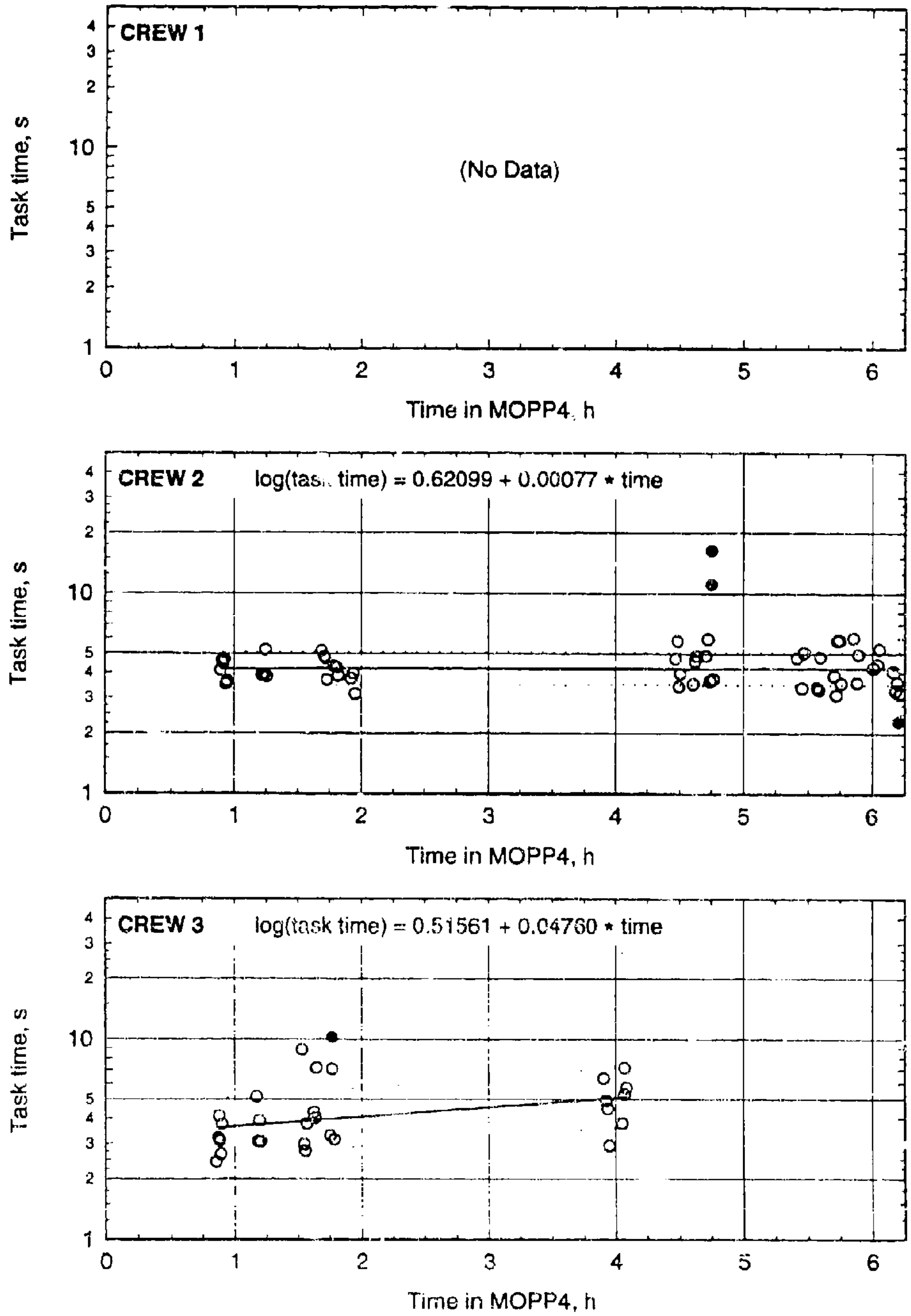


Figure C-53. Task times with regression lines for **load projectile** in MOPP4-R.

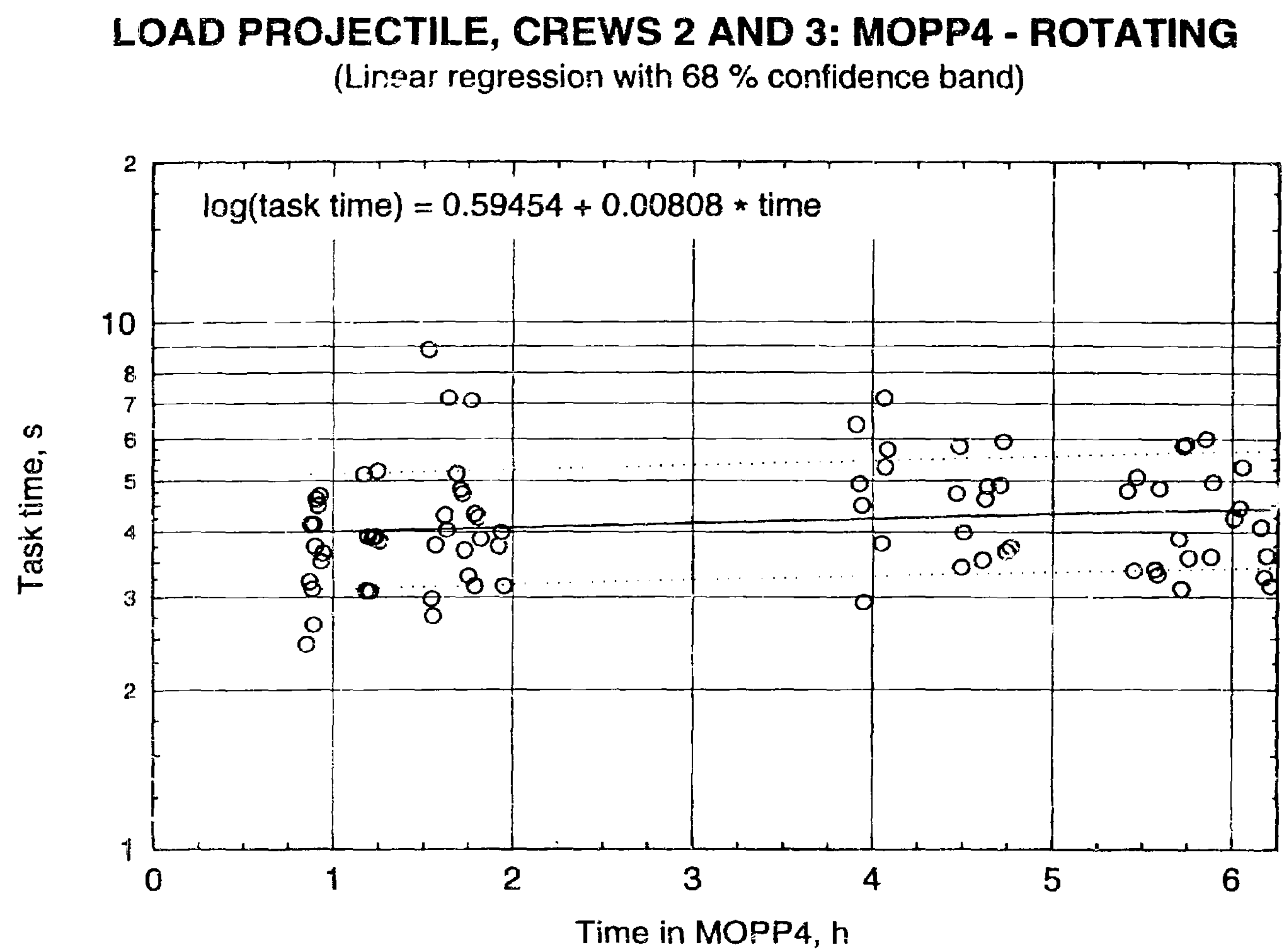


Figure C-54. Aggregate task time data with regression line for **load projectile** in MOPP4-R.

Table C-53. Statistical summary[1] for **load projectile** with crews in MOPP4-R.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	No Data	.62397	.61492	.62080
Number of Observations		52	28	80
Total Sum of Squares		.32201	.61394	.93744
Residual Sum of Squares		.32189	.51577	.91709
Std. Dev. of Estimate		.08024	.14085	.10843
R-squared		.00039	.15990	.02172
Adjusted R-squared		-.01961	.12759	.00917
Degrees of Freedom (df)		50	26	78
Number of Ind Vars (K)		2	2	2
F(K-1, df)		.01934	4.94873	1.73140
Prob. Value of F		.88995	.03500	.19209
Constant		.62099	.51561	.59454
Standard error		.02417	.05198	.02335
Slope		.00077	.04760	.00808
Standard error		.00554	.02140	.00614
t-ratio		.13907	2.22457	1.31583
prob t		.88995	.03500	.19209
Correlation Coefficient		.01966	.39988	.14736

[1]See Section 4 for discussion of regression equations and units.

Table C-54. ANOVA for **load projectile** with crews in MOPP4-R.

	Sum Sq	*DF*	*Mean Sq*
Crew	.00149	1	.93595
Error	.00149	78	.01200

Mean of Dependent Variable	.62080
Number of Observations	80
Total Sum of Squares	.93744
Residual Sum of Squares	.93595
Std. Dev. of Estimate	.10954
R-squared	.00159
Adjusted R-squared	-.01121
Degrees of Freedom (df)	78
Number of Ind Vars (K)	2
F(K-1, df)	.12423
Prob. Value of F	.72544

LOAD FIRST POWDER: BATTLE DRESS UNIFORM

(Linear regression with 68 % confidence band)

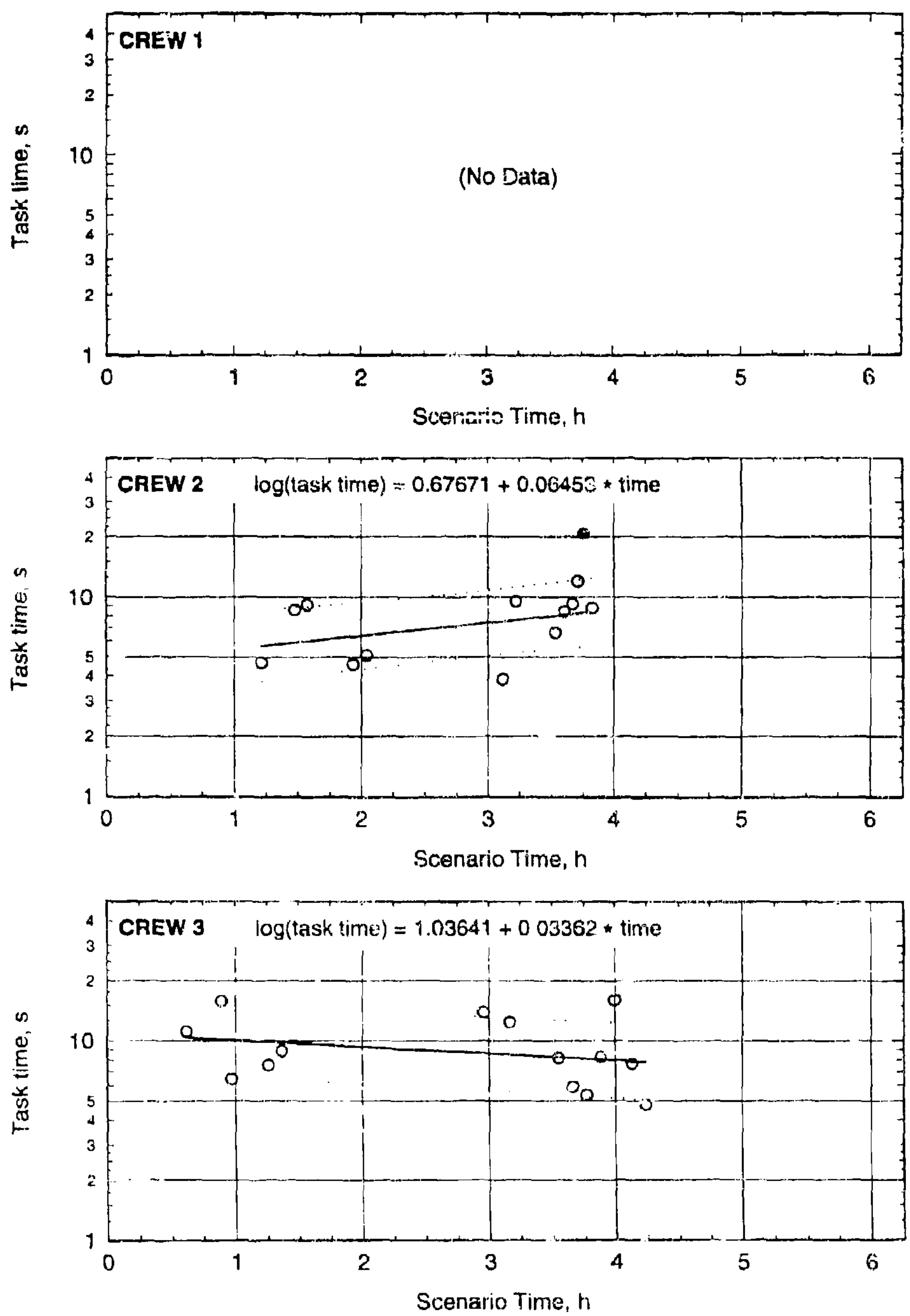


Figure C-55. Task times with regression lines for **load first powder** in BDU.

LOAD FIRST POWDER, CREWS 2 AND 3: BATTLE DRESS UNIFORM

(Linear regression with 68 % confidence band)

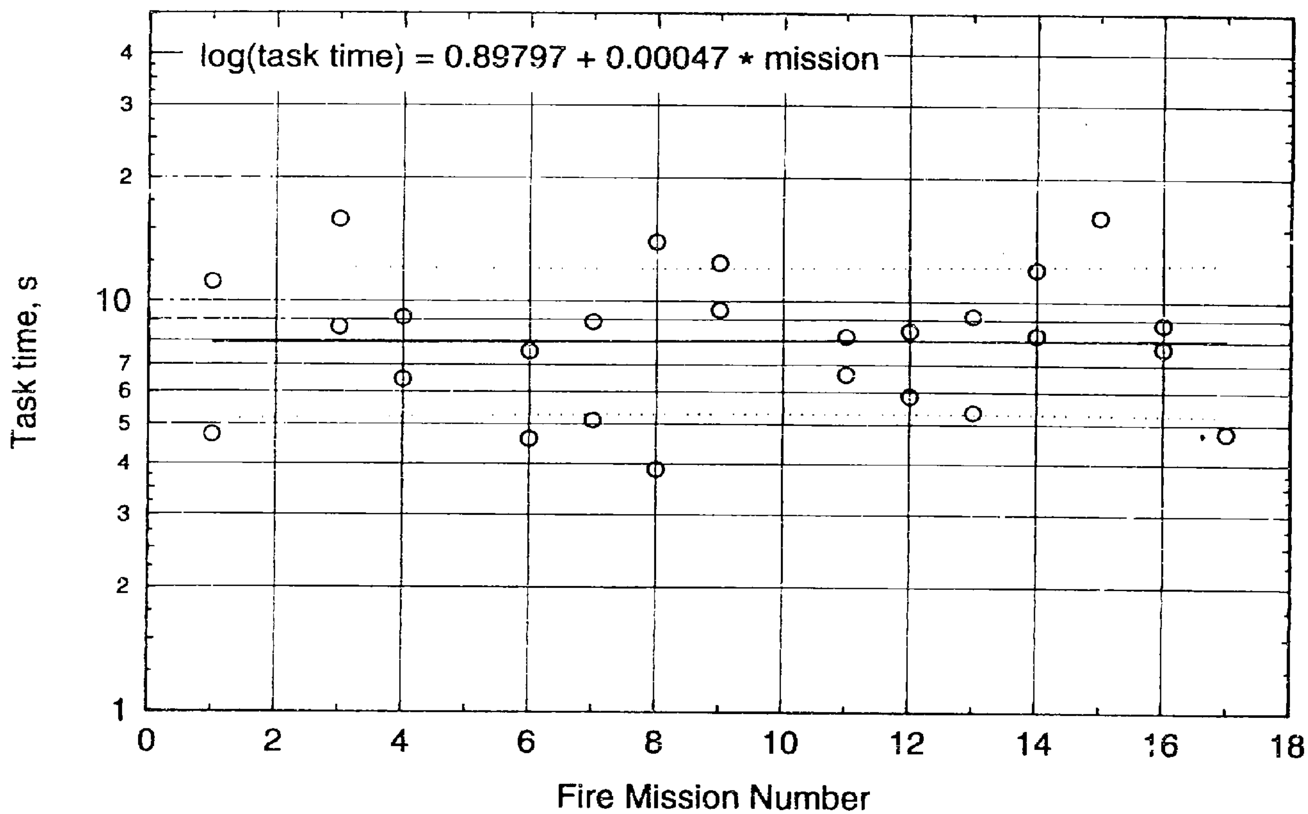


Figure C-56. Aggregate task time data with regression line for **load first powder** in BDU.

Table C-55. Statistical summary[1] for **load first powder** with crews in BDU.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	No Data	.85363	.94407	.90233
Number of Observations		12	14	26
Total Sum of Squares		.27164	.38164	.70612
Residual Sum of Squares		.22532	.35336	.70599
Std. Dev. of Estimate		.15011	.17160	.17151
R-squared		.17052	.07410	.00018
Adjusted R-squared		.08757	-.00306	-.04148
Degrees of Freedom (df)		10	12	24
Number of Ind Vars (K)		2	2	2
F(K-1, df)		2.05575	.96031	.00441
Prob. Value of F		.18215	.34645	.94759
Constant		.67671	1.03641	.89797
Standard error		.13078	.10480	.07371
Slope		.06453	-.03362	.00047
Standard error		.04501	.03431	.00711
t-ratio		1.43379	-.97995	.06642
prob t		.18215	.34645	.94759
Correlation Coefficient		.41294	-.27221	.01356

[1]See Section 4 for discussion of regression equations and units.

Table C-56. ANOVA for **load first powder** with crews in BDU.

	Sum Sq	*DF*	*Mean Sq*
Crew	.05235	1	.65328
Error	.05285	24	.02722

Mean of Dependent Variable	.90233
Number of Observations	26
Total Sum of Squares	.70612
Residual Sum of Squares	.65328
Std. Dev. of Estimate	.16498
R-squared	.07484
Adjusted R-squared	.03629
Degrees of Freedom (df)	24
Number of Ind Vars (K)	2
F(K-1, df)	1.94146
Prob. Value of F	.17628

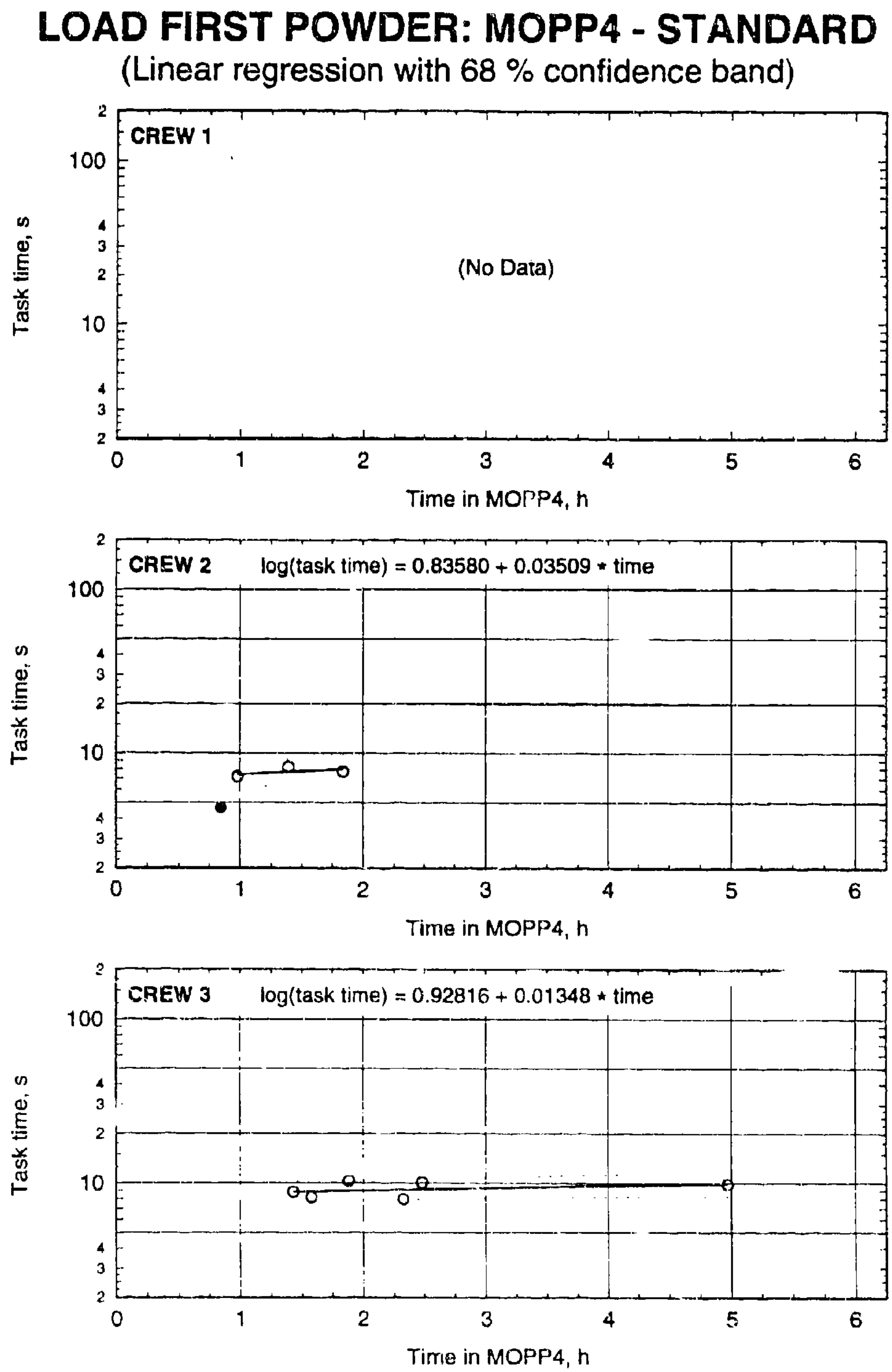


Figure C-57. Task times with regression lines for **load first powder** in MOPP4-S.

LOAD FIRST POWDER, CREWS 2 AND 3: MOPP4 - STANDARD

(Linear regression with 68 % confidence band)

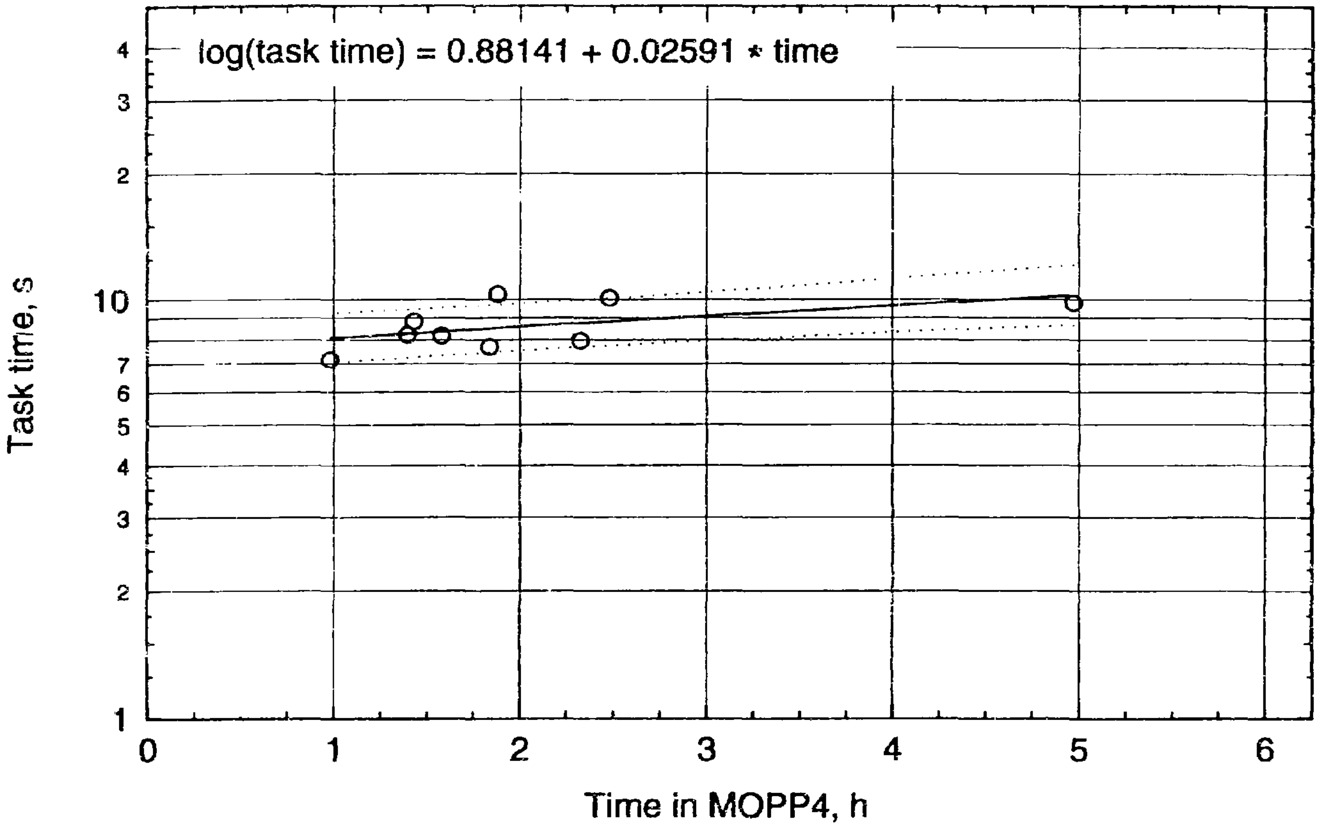


Figure C-58. Aggregate task time data with regression line for **load first powder** in MOPP4-S.

Table C-57. Statistical summary[1] for **load first powder** with crews in MOPP4-S.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	No Data	.88506	.96112	.93577
Number of Observations		3	6	9
Total Sum of Squares		.00177	.01155	.02488
Residual Sum of Squares		.00131	.01000	.01748
Std. Dev. of Estimate		.03623	.05000	.04997
R-squared		.25731	.13367	.29759
Adjusted R-squared		-.48539	-.08292	.19725
Degrees of Freedom (df)		1	4	7
Number of Ind Vars (K)		2	2	2
F(K-1, df)		.34645	.61717	2.96575
Prob. Value of F		.66132	.47603	.12872
Constant		.83580	.92816	.88141
Standard error		.08627	.04665	.03569
Slope		.03509	.01348	.02591
Standard error		.05962	.01716	.01505
t-ratio		.58860	.78560	1.72214
prob t		.66132	.47603	.12872
Correlation Coefficient		.50725	.36561	.54552

[1]See Section 4 for discussion of regression equations and units.

Table C-58. ANOVA for **load first powder** with crews in MOPP4-S.

	Sum Sq	*DF*	*Mean Sq*
Crew	.01157	1	.01331
Error	.01157	7	.00190

Mean of Dependent Variable	.93577
Number of Observations	9
Total Sum of Squares	.02488
Residual Sum of Squares	.01331
Std. Dev. of Estimate	.04361
R-squared	.46498
Adjusted R-squared	.38855
Degrees of Freedom (df)	7
Number of Ind Vars (K)	2
F(K-1, df)	6.08364
Prob. Value of F	.04305

LOAD FIRST POWDER: MOPP4 - ROTATING

(Linear regression with 68 % confidence band)

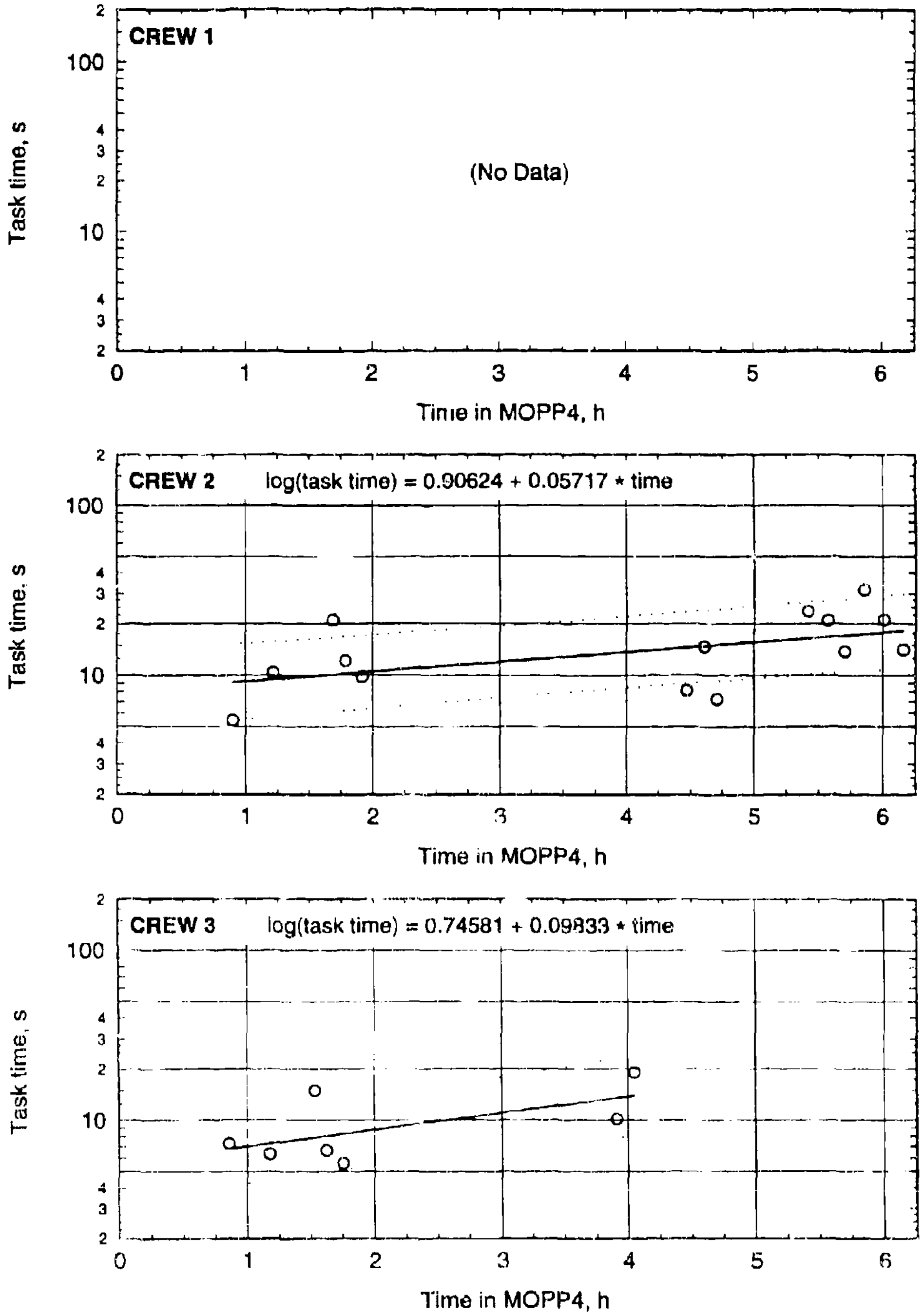


Figure C-59. Task times with regression lines for **load first powder** in M(›PP4-R.

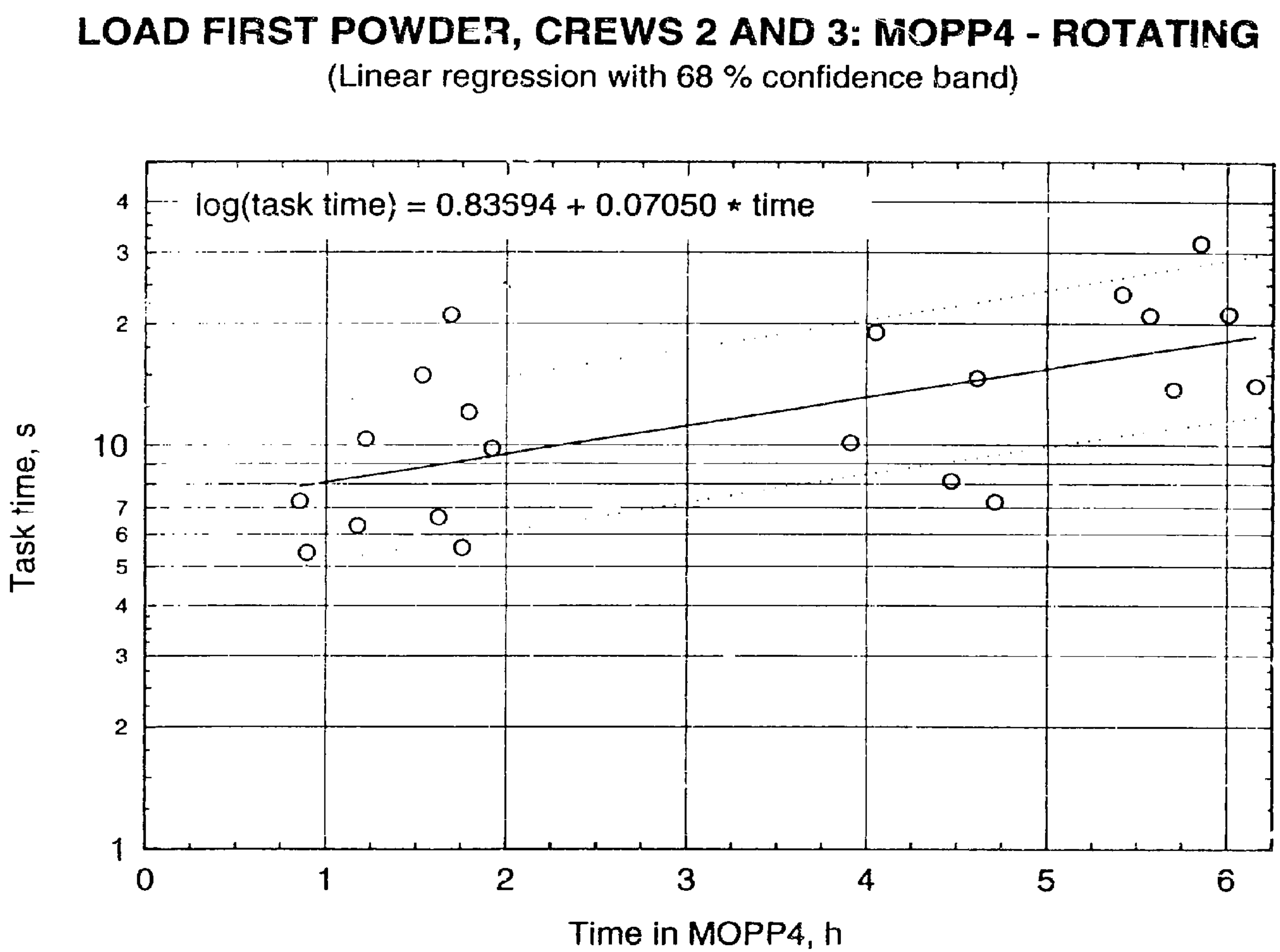


Figure C-60. Aggregate task time data with regression line for **load first powder** in MOPP4-R.

Table C-59. Statistical summary[1] for **load first powder** with crews in MOPP4-R.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	No Data	1.13501	.95507	1.07503
Number of Observations		14	7	21
Total Sum of Squares		.62359	.25133	1.02602
Residual Sum of Squares		.45176	.15322	.63287
Std. Dev. of Estimate		.19403	.17505	.18251
R-squared		.27554	.39037	.38318
Adjusted R-squared		.21517	.26844	.35071
Degrees of Freedom (df)		12	5	19
Number of Ind Vars (K)		2	2	2
F(K-1, df)		4.56414	3.20170	11.80308
Prob. Value of F		.05394	.13358	.00277
Constant		.90624	.74581	.83694
Standard error		.11898	.13437	.07993
Slope		.05717	.09833	.07050
Standard error		.02676	.05496	.02052
t-ratio		2.13639	1.78933	3.43556
prob t		.05394	.13358	.00277
Correlation Coefficient		.52492	.62480	.61901

[1]See Section 4 for discussion of regression equations and units.

Table C-60. ANOVA for **load first powder** with crews in MOPP4-R.

	Sum Sq	*DF*	*Mean Sq*
Crew	.15110	1	.87492
Error	.15110	19	.04605

Mean of Dependent Variable	1.07503
Number of Observations	21
Total Sum of Squares	1.02602
Residual Sum of Squares	.87492
Std. Dev. of Estimate	.21459
R-squared	.14727
Adjusted R-squared	.10239
Degrees of Freedom (df)	19
Number of Ind Vars (K)	2
F(K-1, df)	3.28127
Prob. Value of F	.08591

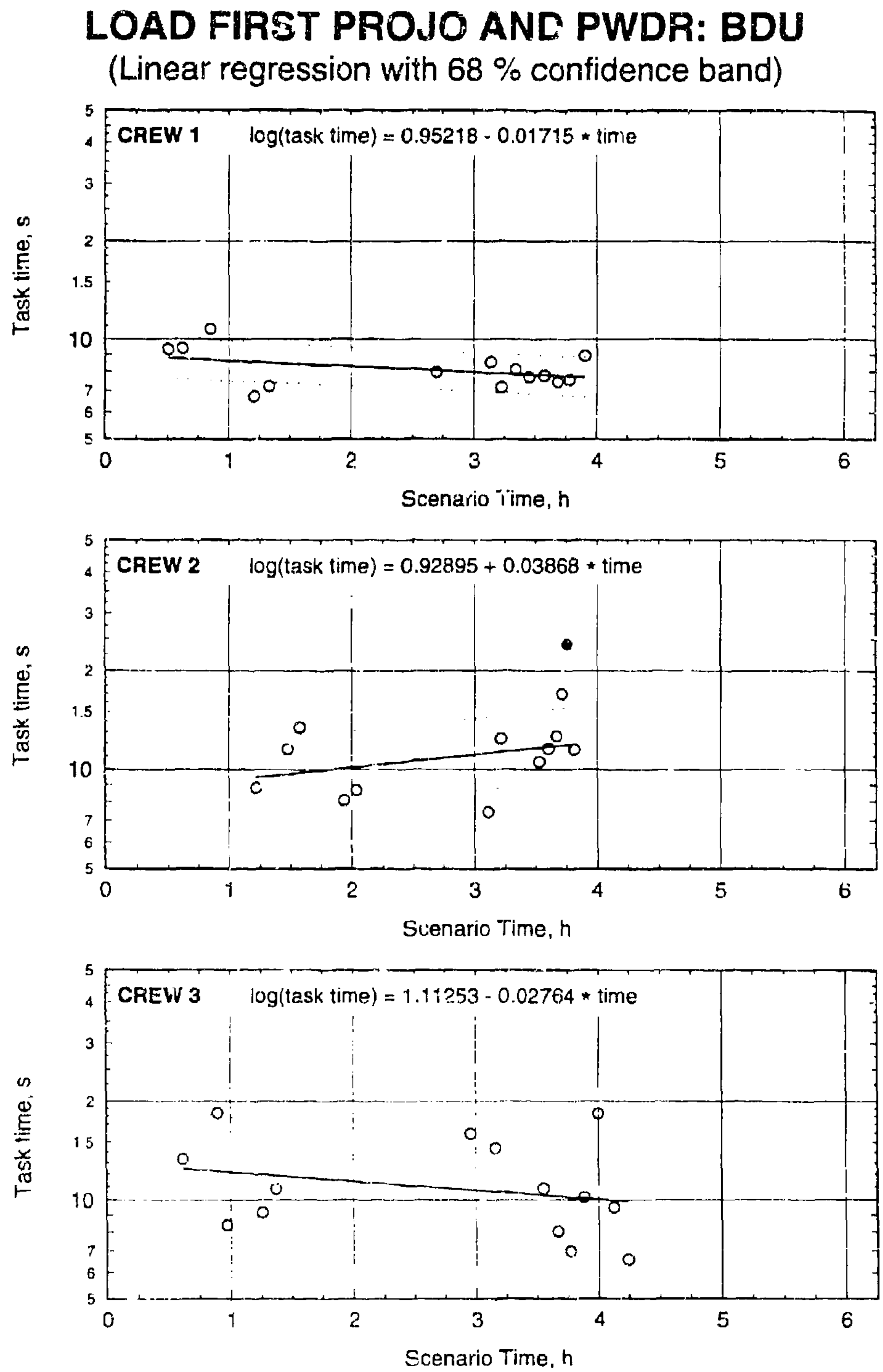


Figure C-61. Task times with regression lines for **load first projo and pwdr** in BDU.

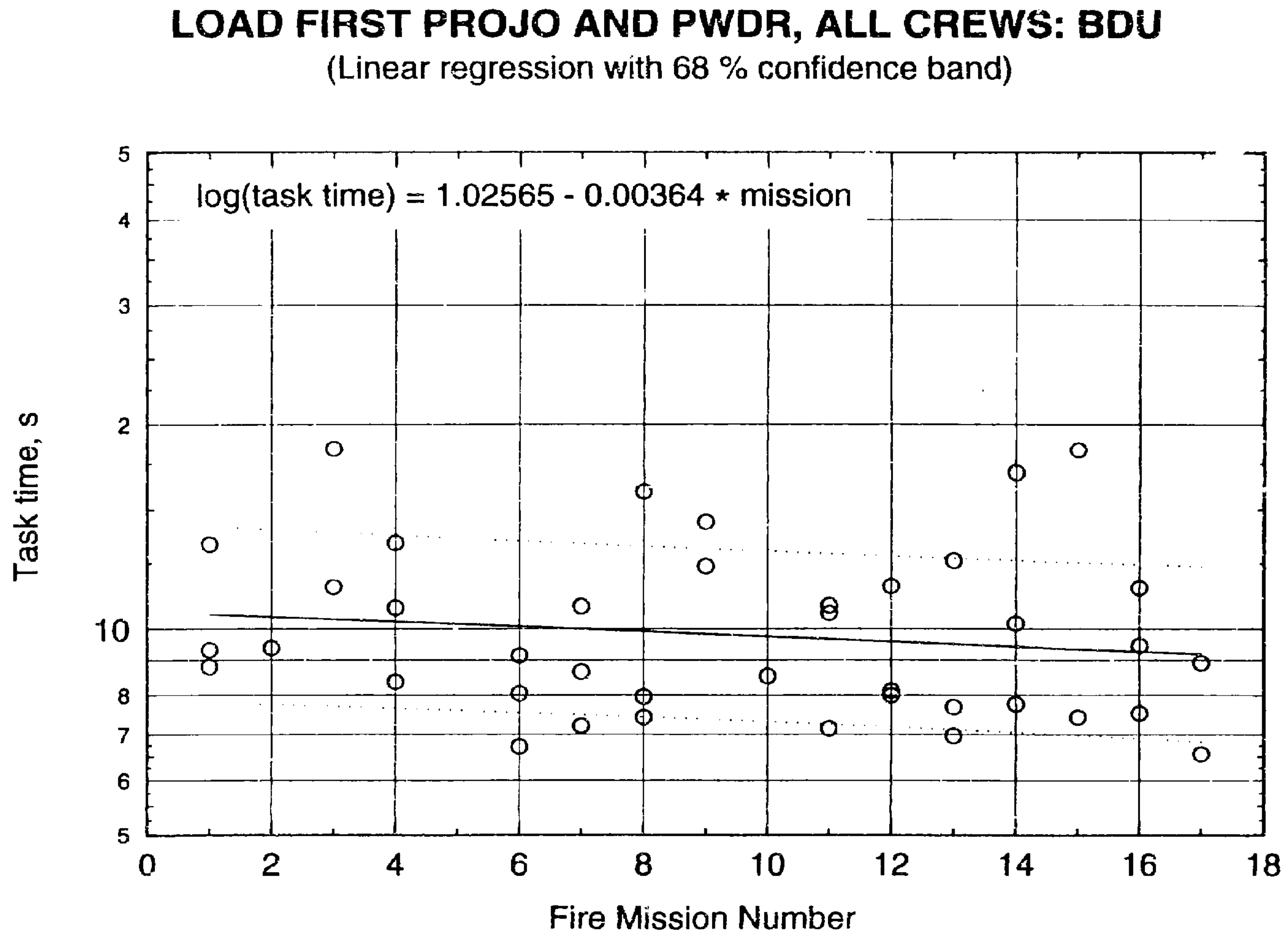


Figure C-62. Aggregate task time data with regression line for **load first projo and pwdr** in BDU.

Table C-61. Statistical summary[1] for **load first projo and pwdr** with crews in BDU.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	.90897	1.03495	1.03665	.99145
Number of Observations	14	12	14	40
Total Sum of Squares	.0[illegible]072	.11822	.28021	.58569
Residual Sum of Squares	.03426	.10158	.26110	.57334
Std. Dev. of Estimate	.05344	.10079	.14751	.12283
R-squared	.15864	.14075	.06818	.02110
Adjusted R-squared	.08852	.05483	-.00947	-.00466
Degrees of Freedom (df)	12	10	12	38
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	2.26254	1.63812	.87800	.81896
Prob. Value of F	.15839	.22948	.36723	.37119
Constant	.95218	.92895	1.11253	1.02565
Standard error	.03208	.08778	.09007	.04249
Slope	-.01715	.03868	-.02764	-.00364
Standard error	.01140	.03022	.02949	.00402
t-ratio	-1.50417	1.27989	-.93702	-.90496
prob t	.15839	.22948	.36723	.37119
Correlation Coefficient	-.39829	.375[illegible]7	-.26111	-.14525

[1]See Section 4 for discussion of regression equations and units.

Table C-62. ANOVA for **load first projo and pwdr** with crews in BDU.

	Sum Sq	*DF*	*Mean Sq*
Crew	.14654	2	.43915
Error	.07327	37	.01187

Mean of Dependent Variable	.99145
Number of Observations	40
Total Sum of Squares	.58569
Residual Sum of Squares	.43915
Std. Dev. of Estimate	.10894
R-squared	.25020
Adjusted R-squared	.20967
Degrees of Freedom (df)	37
Number of Ind Vars (K)	3
F(K-1, df)	6.17333
Prob. Value of F	.00486

LOAD FIRST PROJO AND PWDR: MOPP4 - STANDARD

(Linear regression with 68 % confidence band)

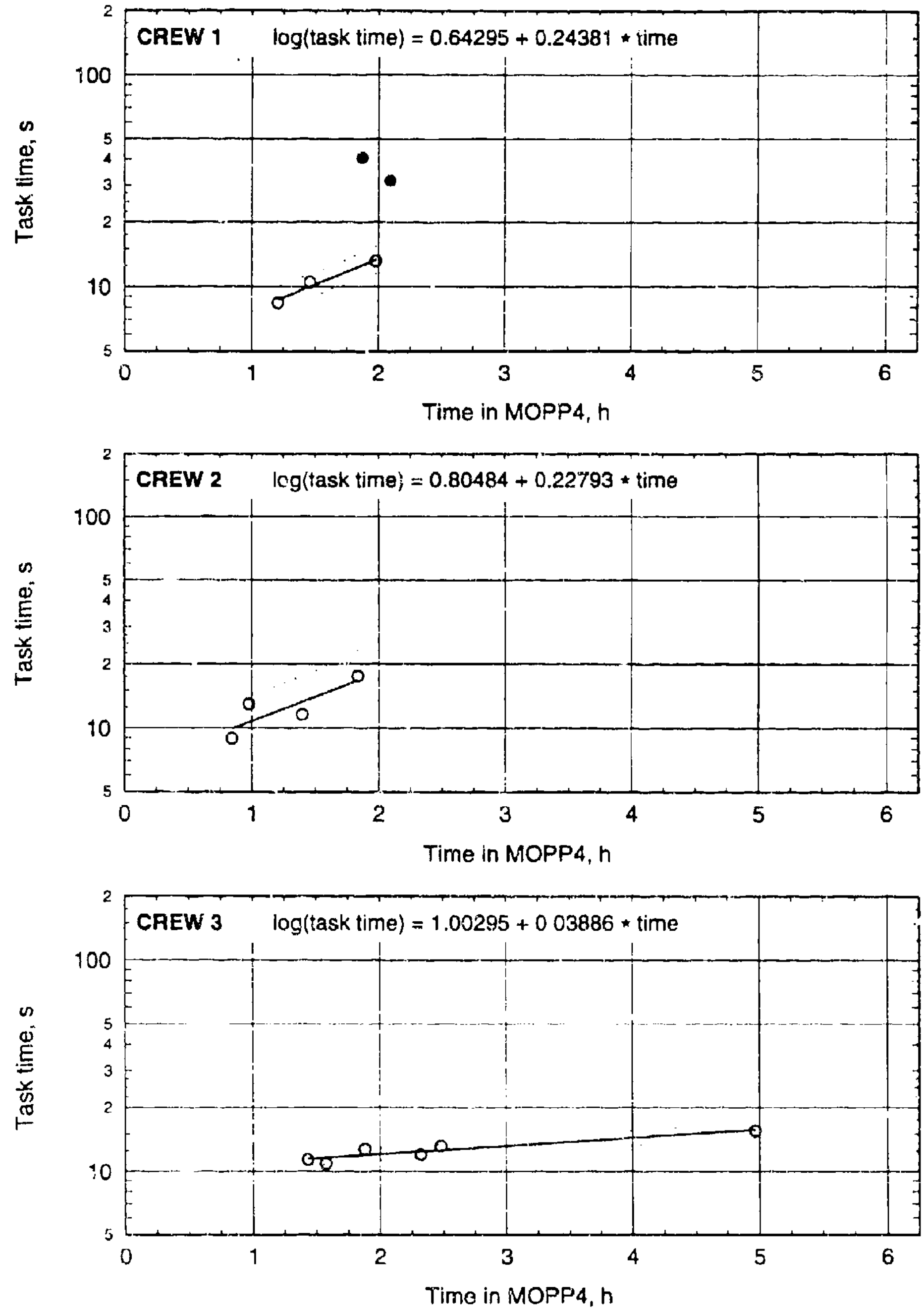


Figure C-63. Task times with regression lines for **load first projo and pwdr** in MOPP4-S.

LOAD FIRST PROJO AND PWDR, ALL CREWS: MOPP4 - STANDARD

(Linear regression with 68 % confidence band)

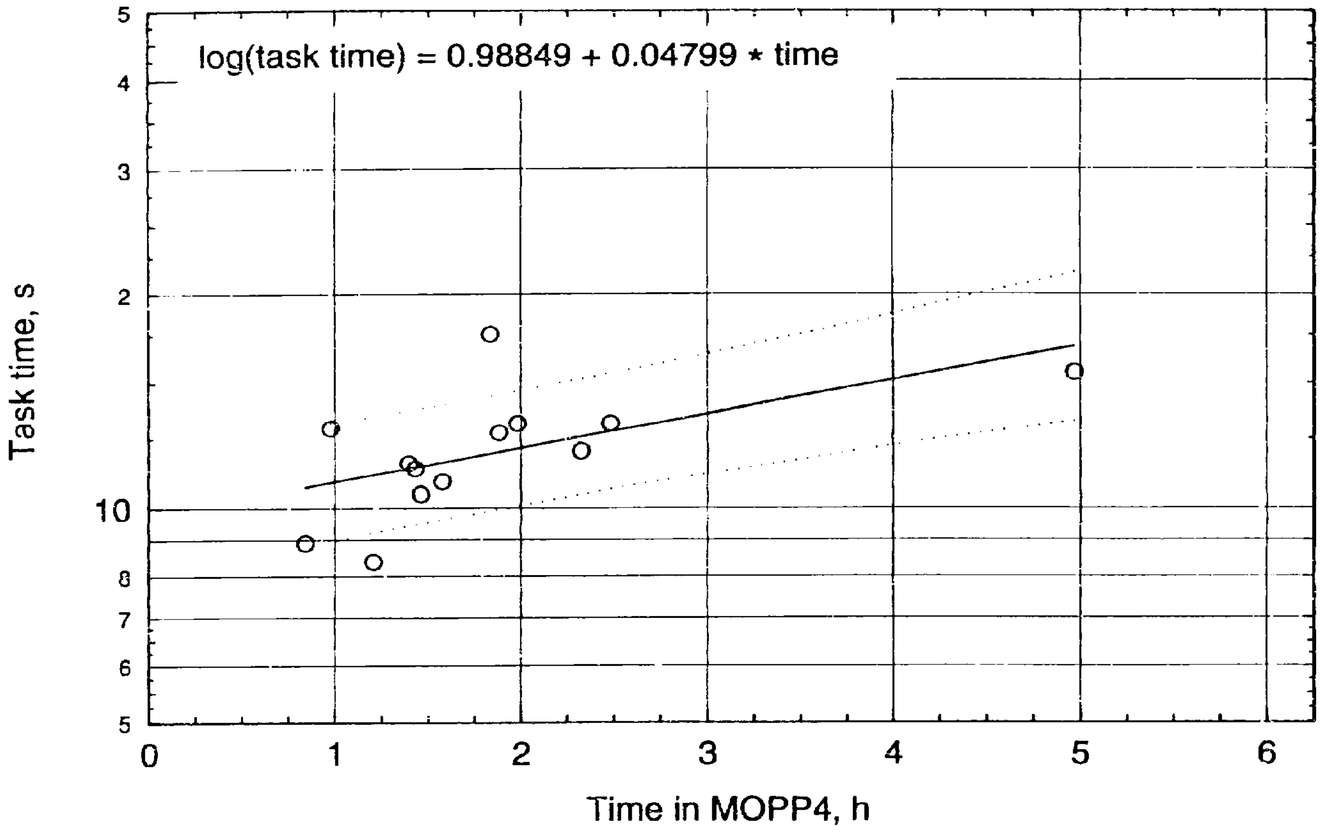


Figure C-64. Aggregate task time data with regression line for **load first projo and pwdr** in MOPP4-S.

Table C-63. Statistical summary[1] for **load first projo and pwdr** with crews in MOPP4-S.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	1.02060	1.09247	1.09792	1.07840
Number of Observations	3	4	6	13
Total Sum of Squares	.01905	.04479	.01509	.09202
Residual Sum of Squares	.00063	.01341	.00227	.06171
Std. Dev. of Estimate	.02507	.08190	.02380	.07490
R-squared	.96702	.70051	.84976	.32940
Adjusted R-squared	.93403	.55076	.81220	.26843
Degrees of Freedom (df)	1	2	4	11
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	29.31776	4.67796	22.62362	5.40317
Prob. Value of F	.11626	.16304	.00893	.04026
Constant	.64295	.80484	1.00295	.98849
Standard error	.07123	.13915	.02221	.04390
Slope	.24381	.22793	.03886	.04799
Standard error	.04503	.10538	.00817	.02064
t-ratio	5.41459	2.16286	4.75643	2.32447
prob t	.11626	.16304	.00893	.04026
Correlation Coefficient	.98337	.83696	.92182	.57393

[1]See Section 4 for discussion of regression equations and units.

Table C-64. ANOVA for **load first projo and pwdr** with crews in MOPP4-S.

	Sum Sq	*DF*	*Mean Sq*
Crew	.01310	2	.07892
Error	.00655	10	.00789

Mean of Dependent Variable	1.07840
Number of Observations	13
Total Sum of Squares	.09202
Residual Sum of Squares	.07892
Std. Dev. of Estimate	.08884
R-squared	.14236
Adjusted R-squared	-.02917
Degrees of Freedom (df)	10
Number of Ind Vars (K)	3
F(K-1, df)	.82992
Prob. Value of F	.46402

LOAD FIRST PROJO AND PWDR: MOPP4 - ROTATING

(Linear regression with 68 % confidence band)

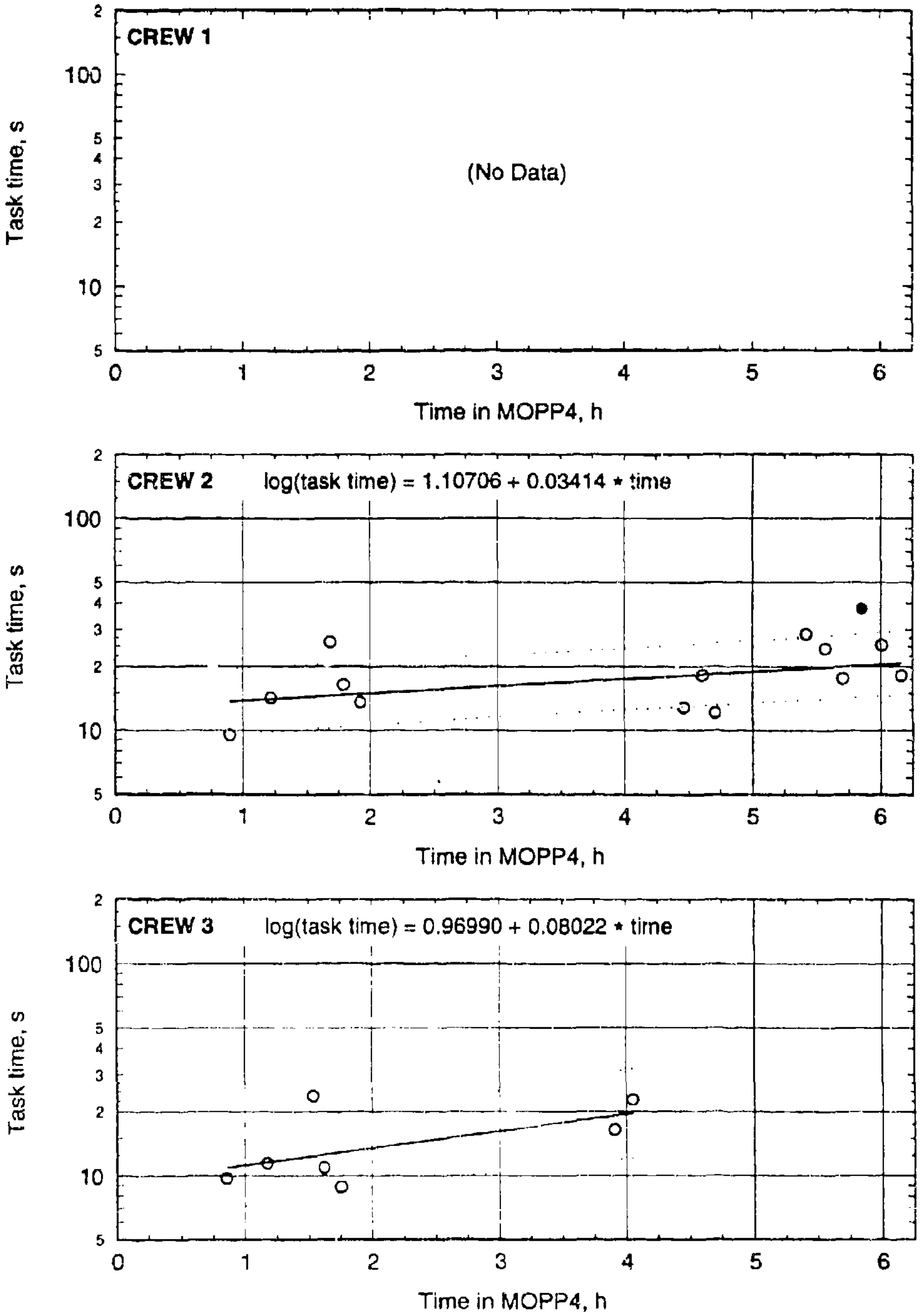


Figure C-65. Task times with regression lines for **load first projo and pwdr** in MOPP4-R.

LOAD FIRST PROJO AND PWDR, CREWS 2 AND 3: MOPP4 - ROTATING

(Linear regression with 68 % confidence band)

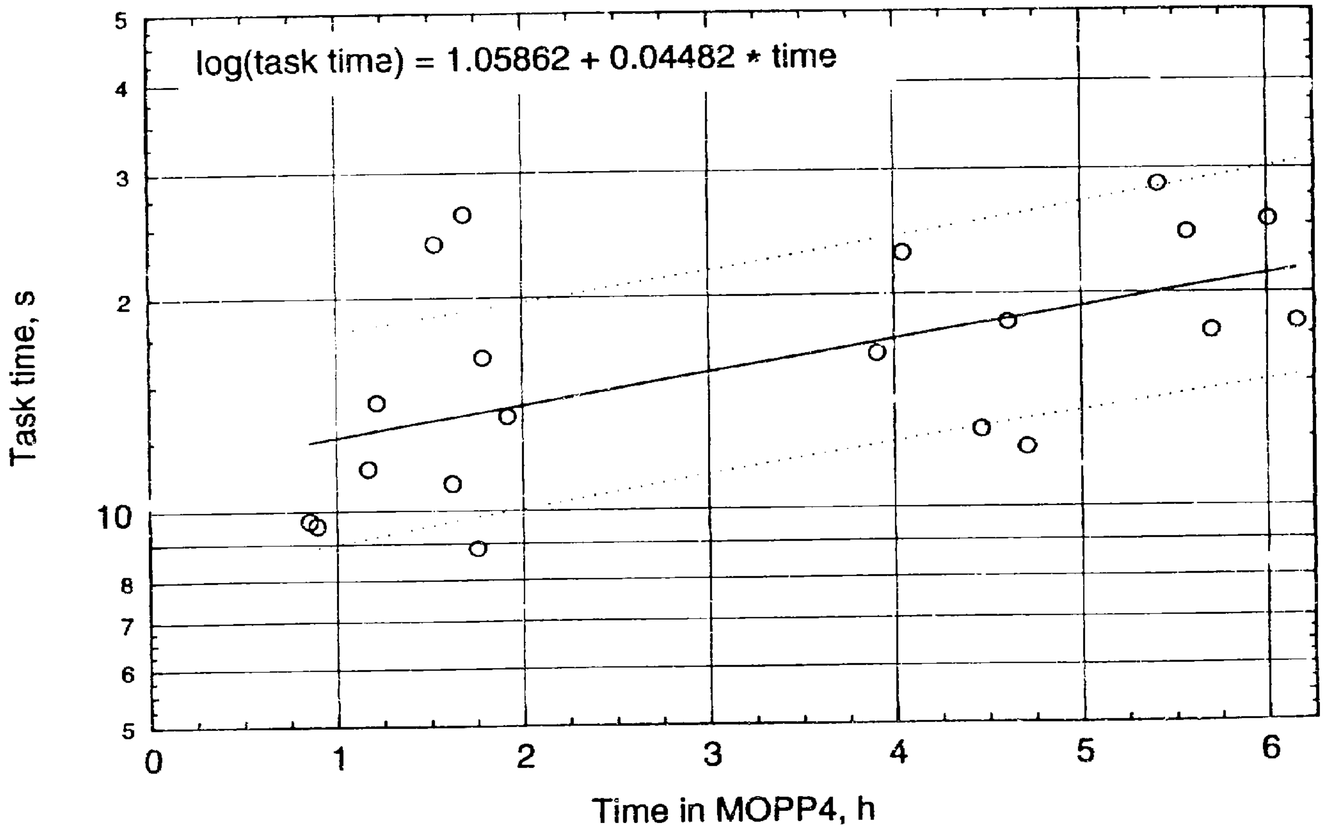


Figure C-66. Aggregate task time data with regression line for **load first projo and pwdr** in MOPP4 R.

Table C-65. Statistical summary[1] for **load first projo and pwdr** with crews in MOPP4-R.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	No Data	1.23878	1.14051	1.20438
Number of Observations		13	7	20
Total Sum of Squares		.25571	.18770	.48734
Residual Sum of Squares		.19873	.12242	.34138
Std. Dev. of Estimate		.13441	.15647	.13772
R-squared		.22280	.34782	.29951
Adjusted R-squared		.15215	.21738	.26059
Degrees of Freedom (df)		11	5	18
Number of Ind Vars (K)		2	2	2
F(K-1, df)		3.15337	2.66657	7.69632
Prob. Value of F		.10341	.16340	.01251
Constant		1.10706	.96990	1.05862
Standard error		.08302	.12005	.06090
Slope		.03414	.08022	.04482
Standard error		.01923	.04912	.01616
t-ratio		1.77577	1.63296	2.77422
prob t		.10341	.16340	.01251
Correlation Coefficient		.47202	.58976	.54728

[1]See Section 4 for discussion of regression equations and units.

Table C-66. ANOVA for **load first projo and pwdr** with crews in MOPP4-R.

	Sum Sq	*DF*	*Mean Sq*
Crew	.04394	1	.44341
Error	.04394	18	.02463

Mean of Dependent Variable	1.20438
Number of Observations	20
Total Sum of Squares	.48734
Residual Sum of Squares	.44341
Std. Dev. of Estimate	.15695
R-squared	.09016
Adjusted R-squared	.03961
Degrees of Freedom (df)	18
Number of Ind Vars (K)	2
F(K-1, df)	1.78365
Prob. Value of F	.19834

LOCK BREECH AND PRIME: BATTLE DRESS UNIFORM

(Linear regression with 68 % confidence band)

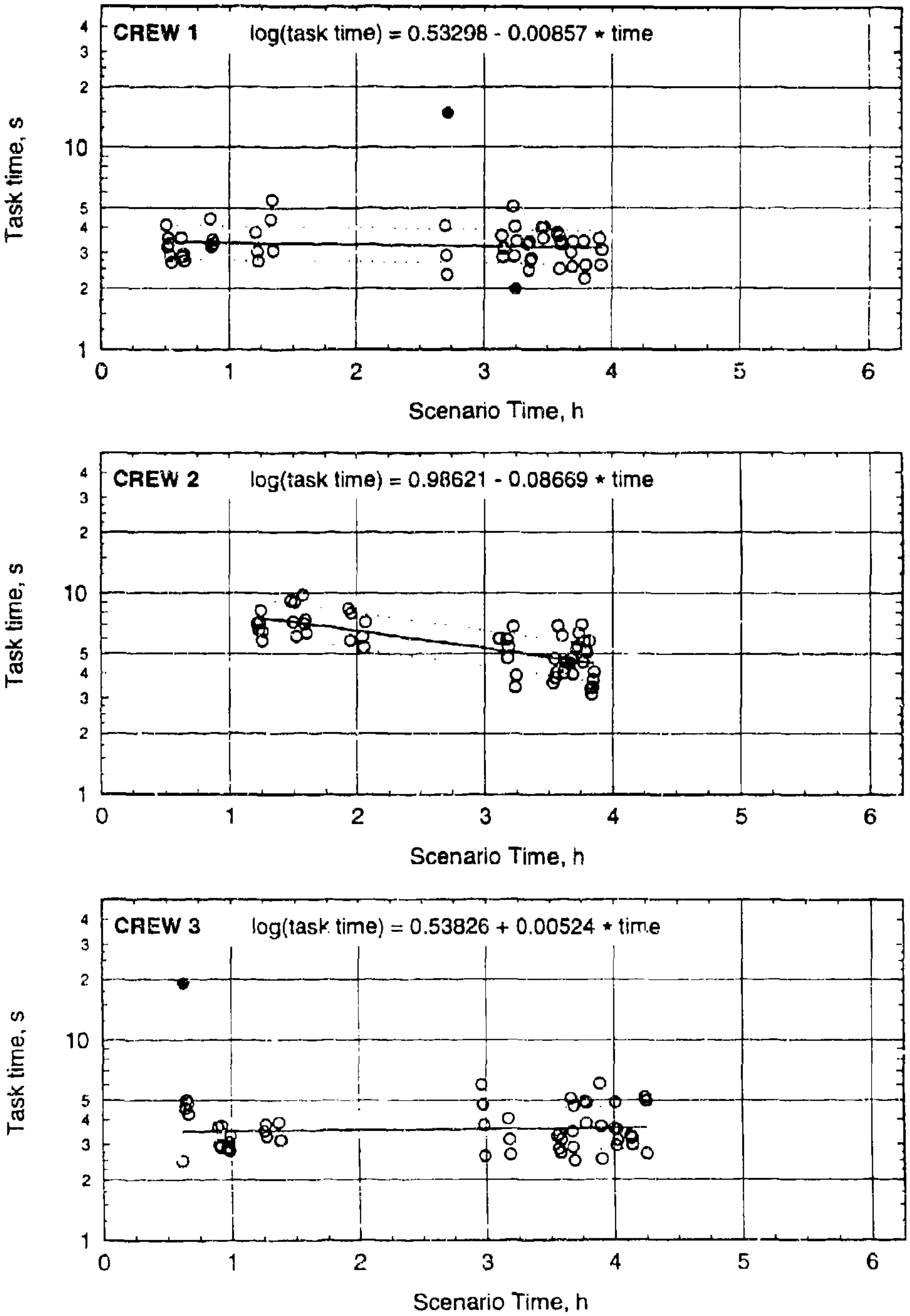


Figure C-67. Task times with regression lines for **lock breech and prime** in BDU.

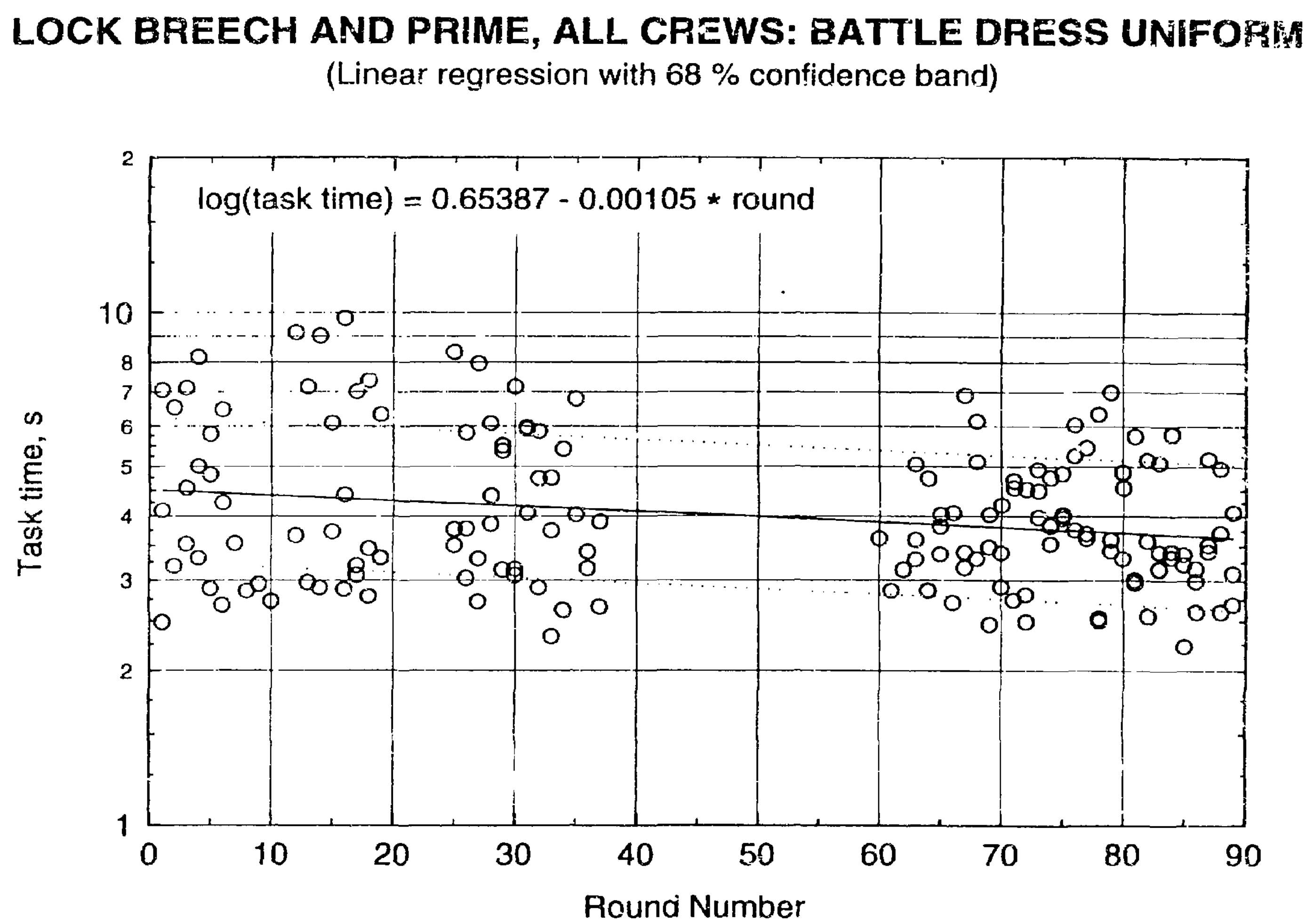


Figure C-68. Aggregate task time data with regression line for **lock breech and prime** in BDU.

Table C-67. Statistical summary[1] for **lock breech and prime** with crews in BDU.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	.51211	.73872	.55257	.60256
Number of Observations	52	54	53	159
Total Sum of Squares	.34161	.80985	.54597	3.25646
Residual Sum of Squares	.33517	.40154	.54332	3.10120
Std. Dev. of Estimate	.08187	.08787	.10321	.14054
R-squared	.01886	.50419	.00485	.04768
Adjusted R-squared	-.00076	.49465	-.01466	.04161
Degrees of Freedom (df)	50	52	51	157
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	.96111	52.87798	.24867	7.86013
Prob. Value of F	.33163	.00000	.62016	.00569
Constant	.53298	.98621	.53826	.65387
Standard error	.02412	.03607	.03201	.02143
Slope	-.00857	-.08669	.00524	-.00105
Standard error	.00874	.01192	.01051	.00038
t-ratio	-.98036	-7.27172	.49867	-2.80359
prob t	.33163	.00000	.62016	.00569
Correlation Coefficient	-.13733	-.71006	.06966	-.21835

[1]See Section 4 for discussion of regression equations and units.

Table C-68. ANOVA for **lock breech and prime** with crews in BDU.

	Sum Sq	*DF*	*Mean Sq*
Crew	1.55902	2	1.69744
Error	.77951	156	.01088

Mean of Dependent Variable	.60256
Number of Observations	159
Total Sum of Squares	3.25646
Residual Sum of Squares	1.69744
Std. Dev. of Estimate	.10431
R-squared	.47875
Adjusted R-squared	.47206
Degrees of Freedom (df)	156
Number of Ind Vars (K)	3
F(K-1, df)	71.63951
Prob. Value of F	.00000

LOCK BREECH AND PRIME: MOPP4 - STANDARD

(Linear regression with 68 % confidence band)

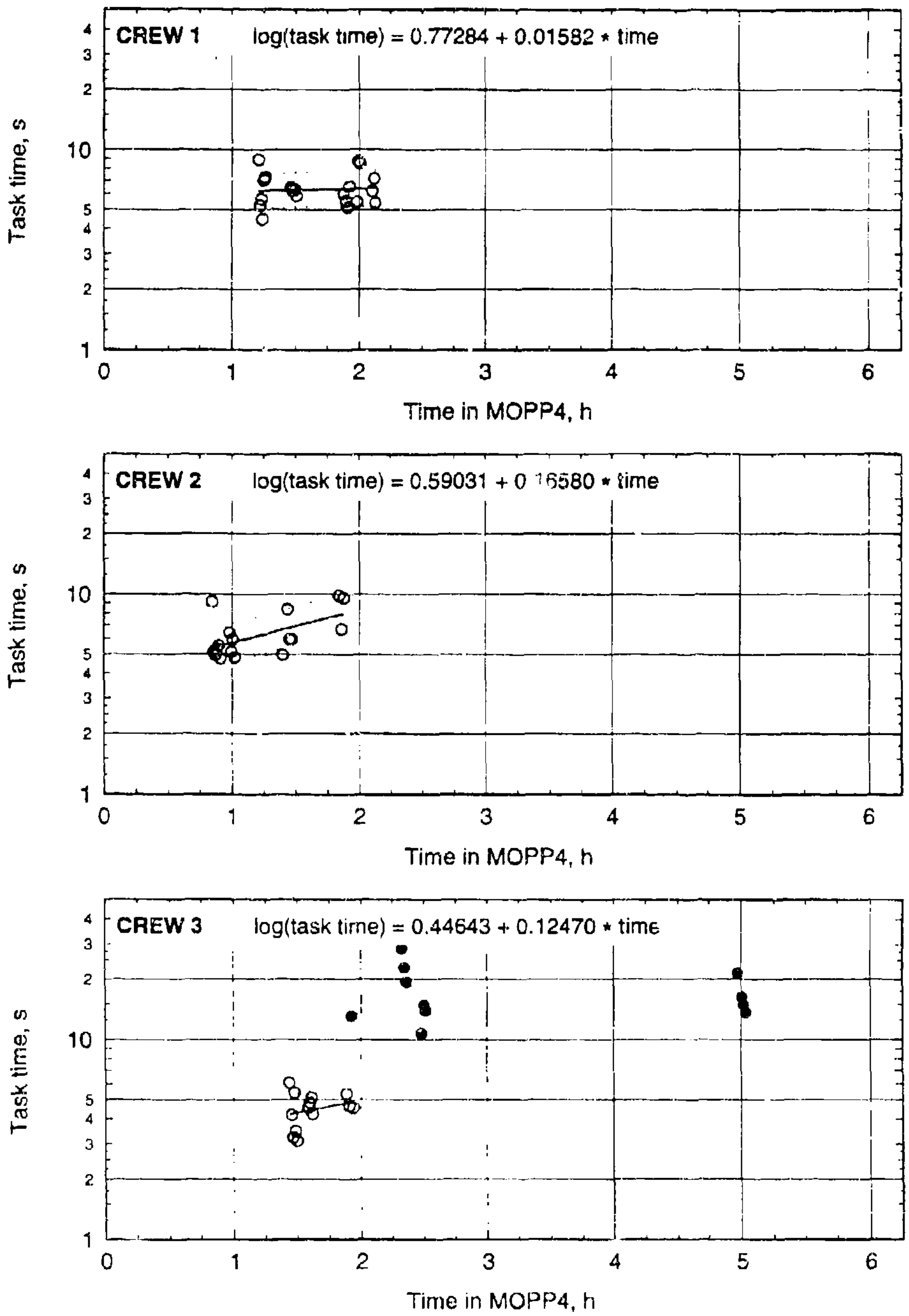


Figure C-69. Task times with regression lines for **lock breech and prime** in MOPP4-S.

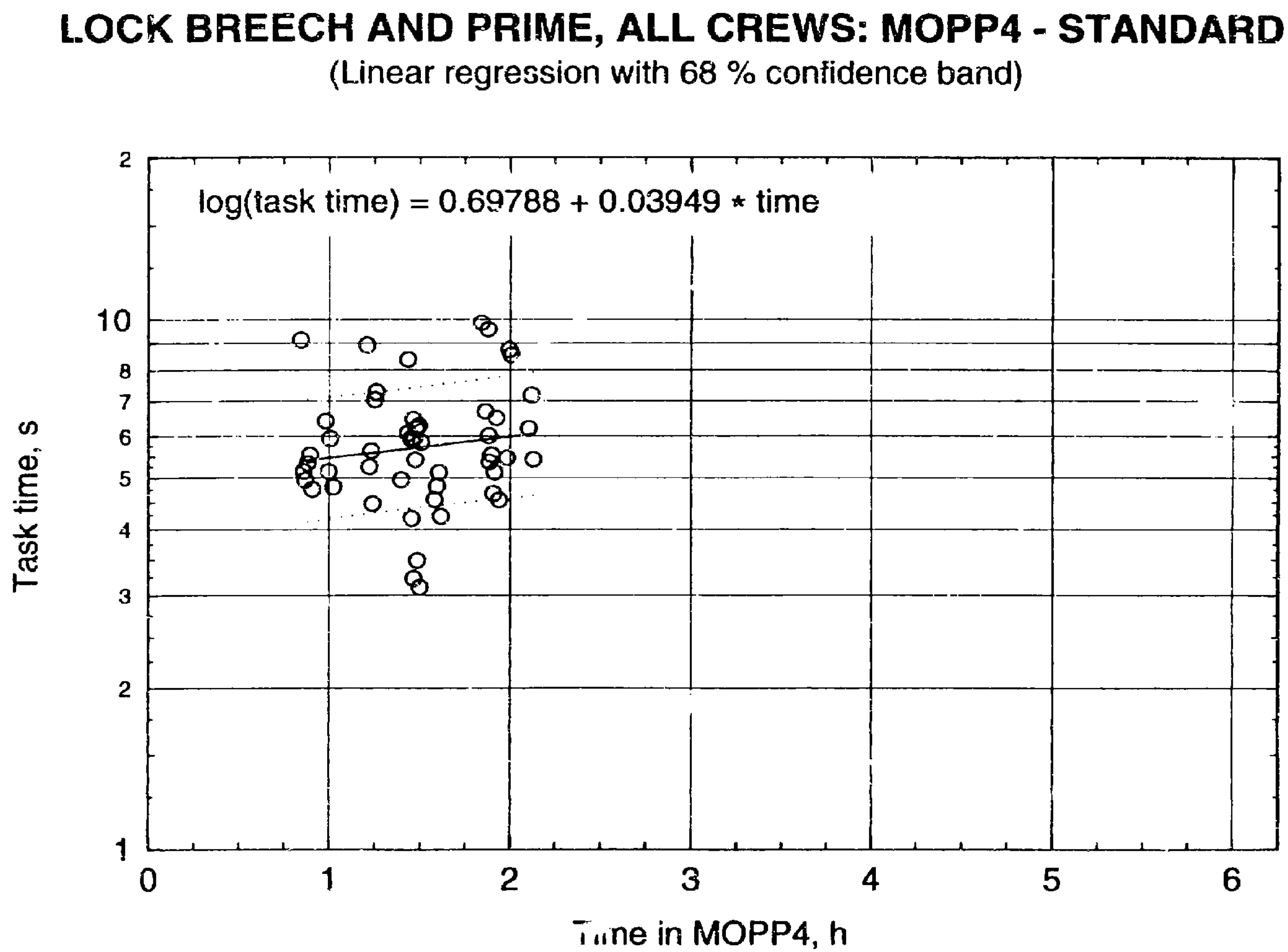


Figure C-70. Aggregate task time data with regression line for **lock breech and prime** in MOPP4-S.

Table C-69. Statistical summary[1] for **lock breech and prime** with crews in MOPP4-S.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	.79918	.79119	.64735	.75699
Number of Observations	20	17	13	50
Total Sum of Squares	.12226	.18741	.09330	.61472
Residual Sum of Squares	.12165	.12353	.08714	.60342
Std. Dev. of Estimate	.08221	.09075	.08900	.11212
R-squared	.00492	.34084	.06600	.01838
Adjusted R-squared	-.05036	.29690	-.01891	-.00207
Degrees of Freedom (df)	18	15	11	48
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	.08902	7.75623	.77734	.89875
Prob. Value of F	.76885	.01387	.39681	.34787
Constant	.77284	.59031	.44643	.69788
Standard error	.09020	.07541	.22922	.06434
Slope	.01582	.16580	.12470	.03949
Standard error	.05302	.05953	.14144	.04165
t-ratio	.29836	2.78500	.88167	.94802
prob t	.76885	.01387	.39681	.34787
Correlation Coefficient	.07015	.58381	.25691	.13557

[1]See Section 4 for discussion of regression equations and units.

Table C-70. ANOVA for **lock breech and prime** with crews in MOPP4-S.

	Sum Sq	*DF*	*Mean Sq*
Crew	.21175	2	.40296
Error	.10588	47	.00857

Mean of Dependent Variable	.75699
Number of Observations	50
Total Sum of Squares	.61472
Residual Sum of Squares	.40296
Std. Dev. of Estimate	.09259
R-squared	.34447
Adjusted R-squared	.31658
Degrees of Freedom (df)	47
Number of Ind Vars (K)	3
F(K-1, df)	12.34894
Prob. Value of F	00005

LOCK BREECH AND PRIME: MOPP4 - ROTATING
(Linear regression with 68 % confidence band)

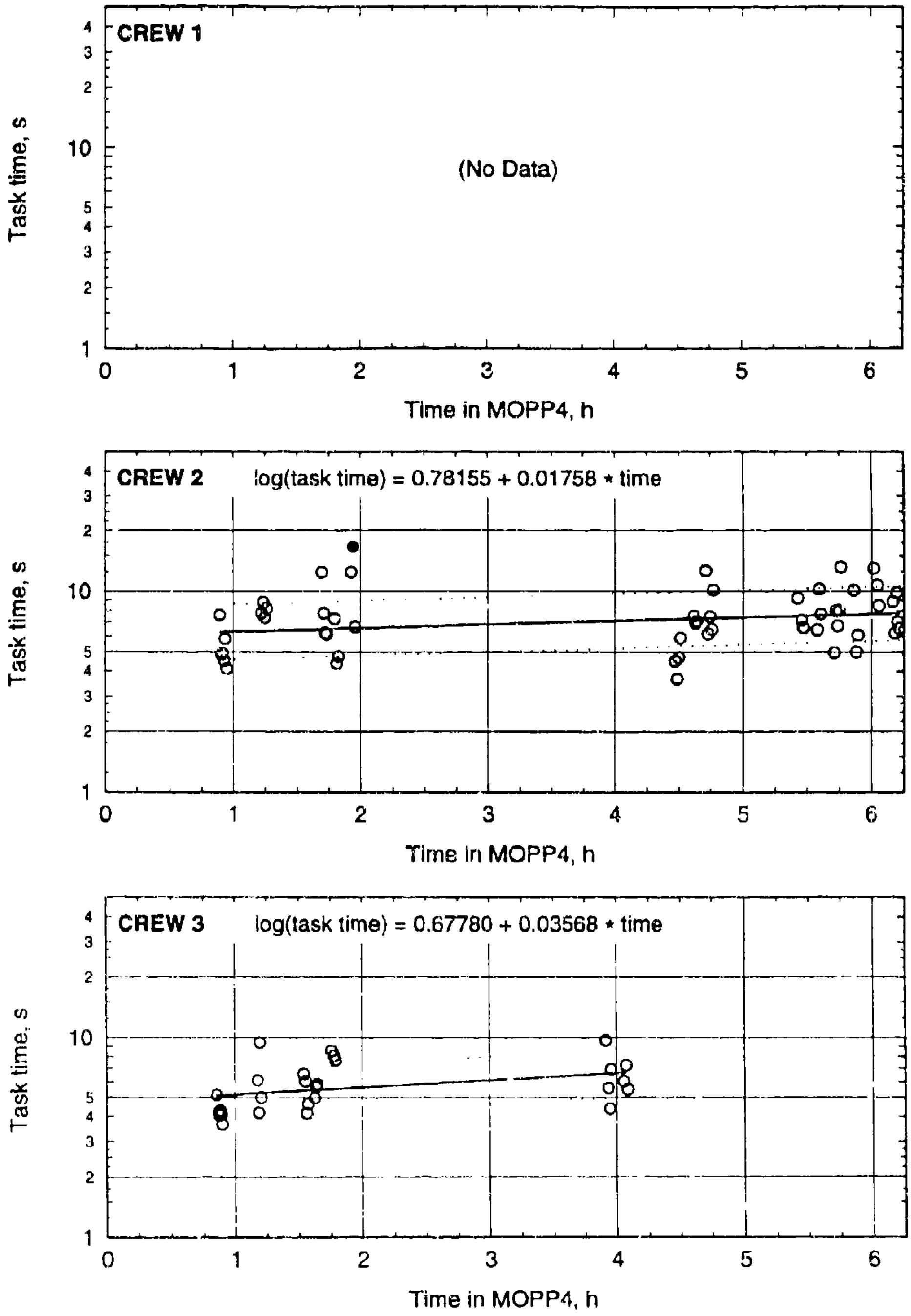


Figure C-71. Task times with regression lines for **lock breech and prime** in MOPP4-R.

LOCK BREECH AND PRIME, CREWS 2 AND 3: MOPP4 - ROTATING

(Linear regression with 68 % confidence band)

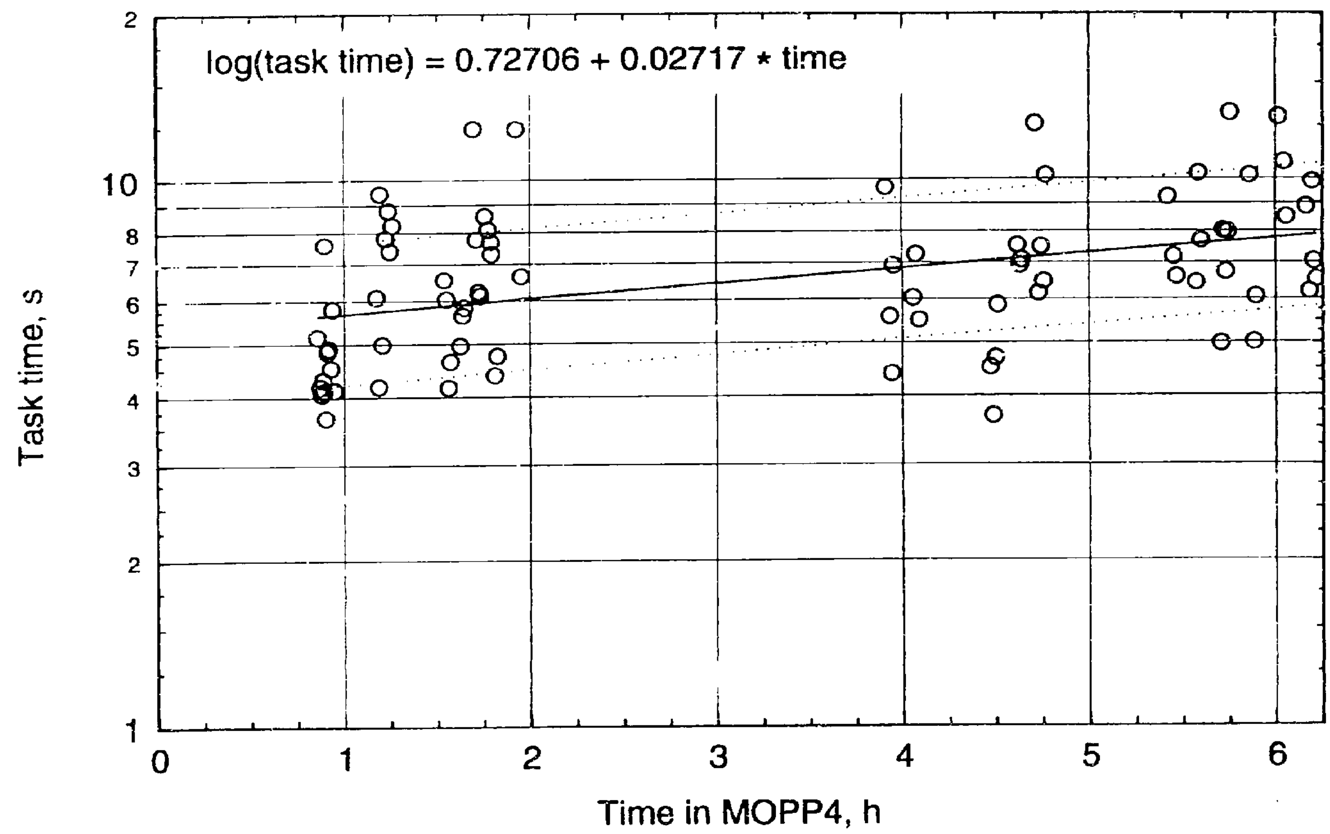


Figure C-72. Aggregate task time data with regression line for **lock breech and prime** in MOPP4-R.

Table C-71. Statistical summary[1] for **lock breech and prime** with crews in MOPP4-R.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	No Data	.85146	.74975	.81713
Number of Observations		53	27	80
Total Sum of Squares		.96275	.37342	1.52124
Residual Sum of Squares		.89719	.32338	1.28493
Std. Dev. of Estimate		.13263	.11373	.12835
R-squared		.06809	.13401	.15534
Adjusted R-squared		.04982	.09937	.14451
Degrees of Freedom (df)		51	25	78
Number of Ind Vars (K)		2	2	2
F(K-1, df)		3.72654	3.86861	14.34510
Prob. Value of F		.05912	.06039	.00030
Constant		.78155	.67780	.72706
Standard error		.04054	.04263	.02778
Slope		.01758	.03568	.02717
Standard error		.00911	.01814	.00717
t-ratio		1.93043	1.96688	3.78749
prob t		.05912	.06039	.00030
Correlation Coefficient		.26095	.36607	.39413

[1]See Section 4 for discussion of regression equations and units.

Table C-72. ANOVA for **lock breech and prime** with crews in MOPP4-R.

	Sum Sq	*DF*	*Mean Sq*
Crew	.18508	1	1.33617
Error	.18508	78	.01713

Mean of Dependent Variable	.81713
Number of Observations	80
Total Sum of Squares	1.52124
Residual Sum of Squares	1.33617
Std. Dev. of Estimate	.13088
R-squared	.12166
Adjusted R-squared	.11040
Degrees of Freedom (df)	78
Number of Ind Vars (K)	2
F(K-1, df)	10.80413
Prob. Value of F	.00152

FIRE: BATTLE DRESS UNIFORM
(Linear regression with 68 % confidence band)

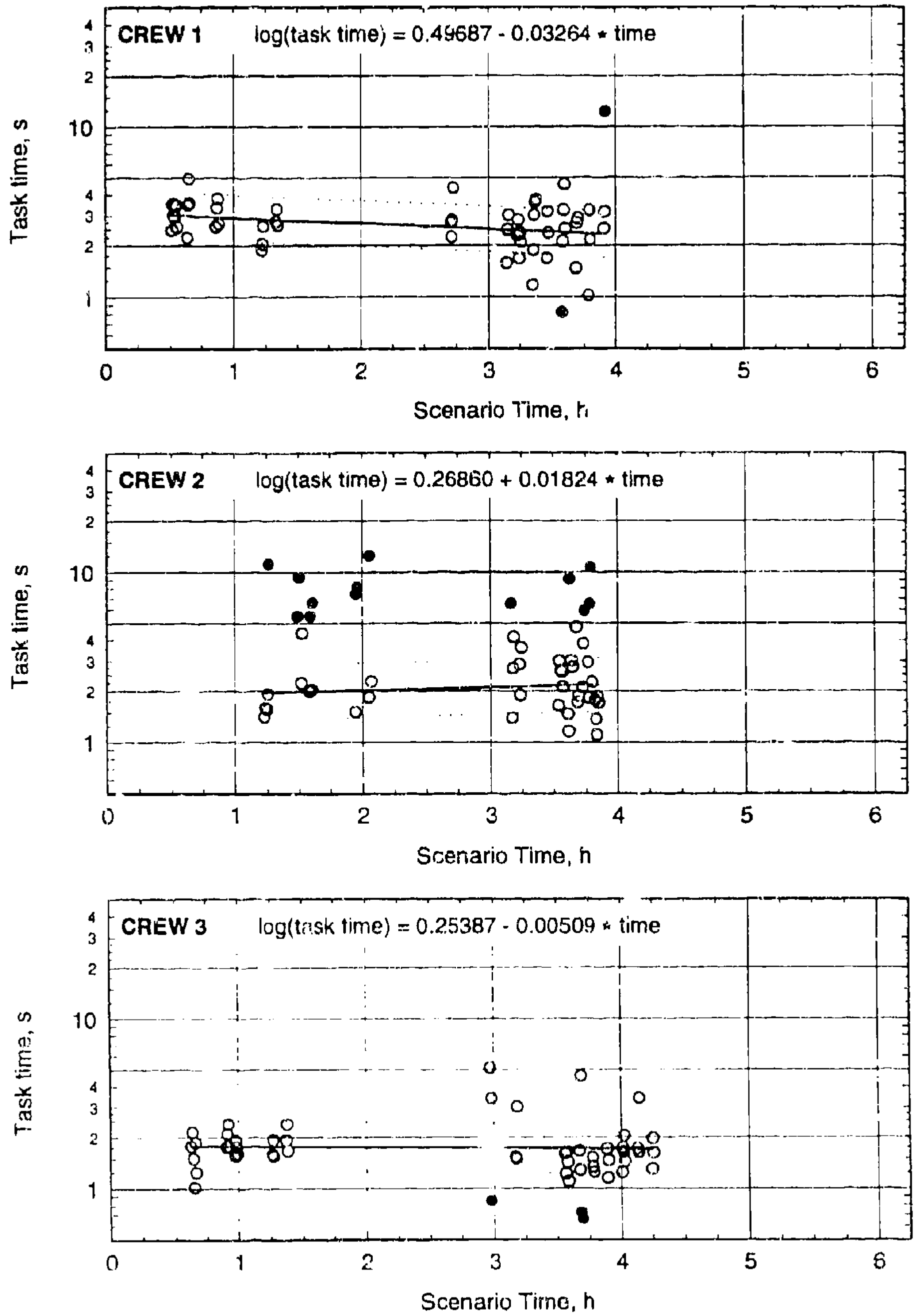


Figure C-73. Task times with regression lines for **fire** in BDU.

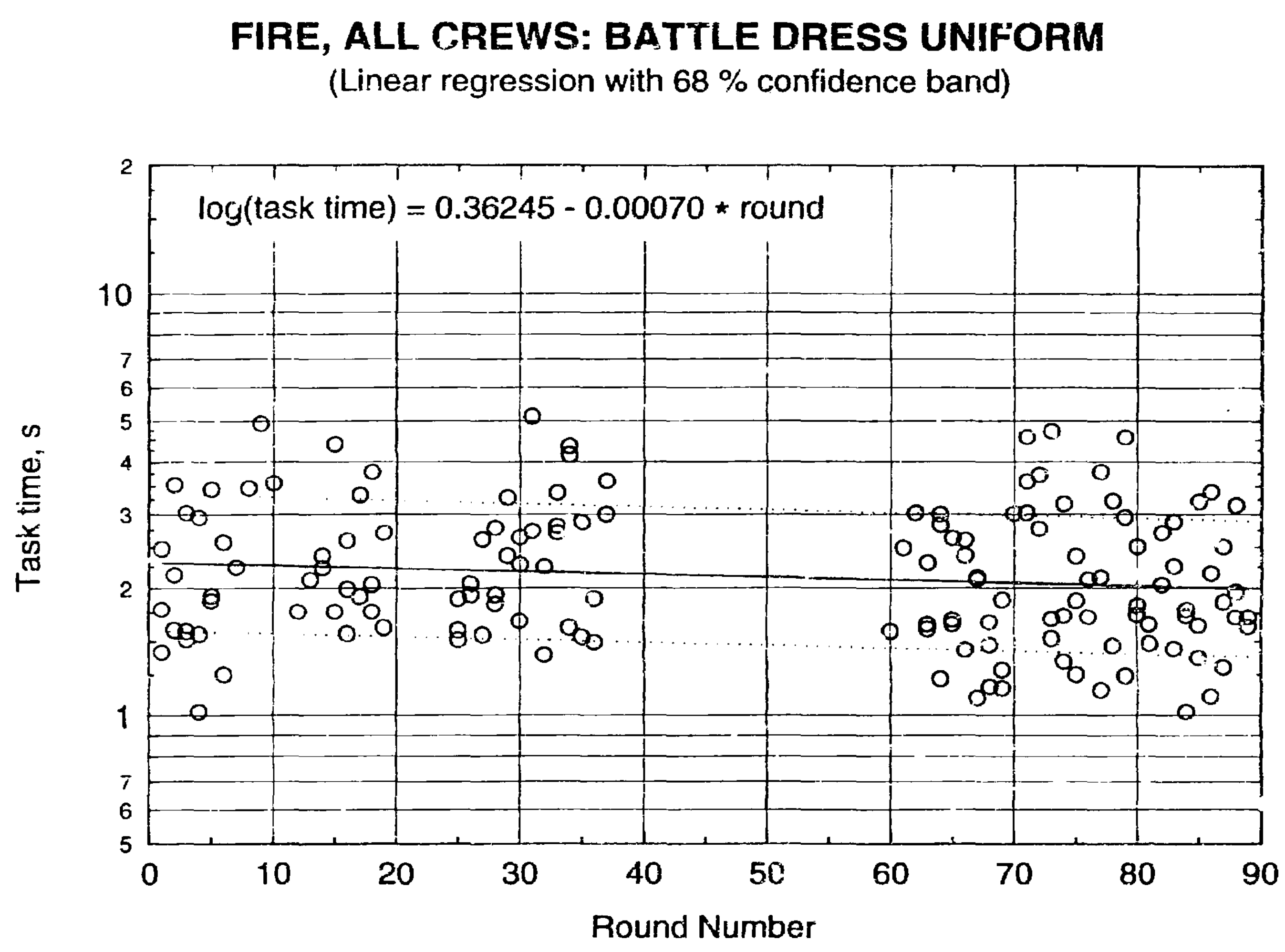


Figure C-74. Aggregate task time data with regression line for fire in BDU.

Table C-73. Statistical summary[1] for **fire** with crews in BDU.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	.41824	.32327	.24039	.32821
Number of Observations	52	41	51	144
Total Sum of Squares	.94805	.95940	.99342	3.71668
Residual Sum of Squares	.85752	.94655	.99087	3.65373
Std. Dev. of Estimate	.13096	.15579	.14220	.16041
R-squared	.09549	.01339	.00257	.01694
Adjusted R-squared	.07740	-.01191	-.01779	.01002
Degrees of Freedom (df)	50	39	49	142
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	5.27836	.52934	.12602	2.44665
Prob. Value of F	.02581	.47123	.72412	.12000
Constant	.49687	.26860	.25387	.36245
Standard error	.03874	.07898	.04286	.02565
Slope	-.03264	.01824	-.00509	-.00070
Standard error	.01421	.02507	.01433	.00045
t-ratio	-2.29747	.727[illegible]	-.35499	-1.56418
prob t	.02581	.47123	.72412	.12000
Correlation Coefficient	-.30901	.11572	-.05065	-.13015

[1]See Section 4 for discussion of regression equations and units.

Table C-74. ANOVA for **fire** with crews in BDU.

	Sum Sq	*DF*	*Mean Sq*
Crew	.81581	2	2.90087
Error	.40790	141	.02057

Mean of Dependent Variable	.32821
Number of Observations	144
Total Sum of Squares	3.71668
Residual Sum of Squares	2.90087
Std. Dev. of Estimate	.14343
R-squared	.21950
Adjusted R-squared	.20843
Degrees of Freedom (df)	141
Number of Ind Vars (K)	3
F(K-1, df)	19.82657
Prob. Value of F	.00000

FIRE: MOPP4 - STANDARD

(Linear regression with 68 % confidence band)

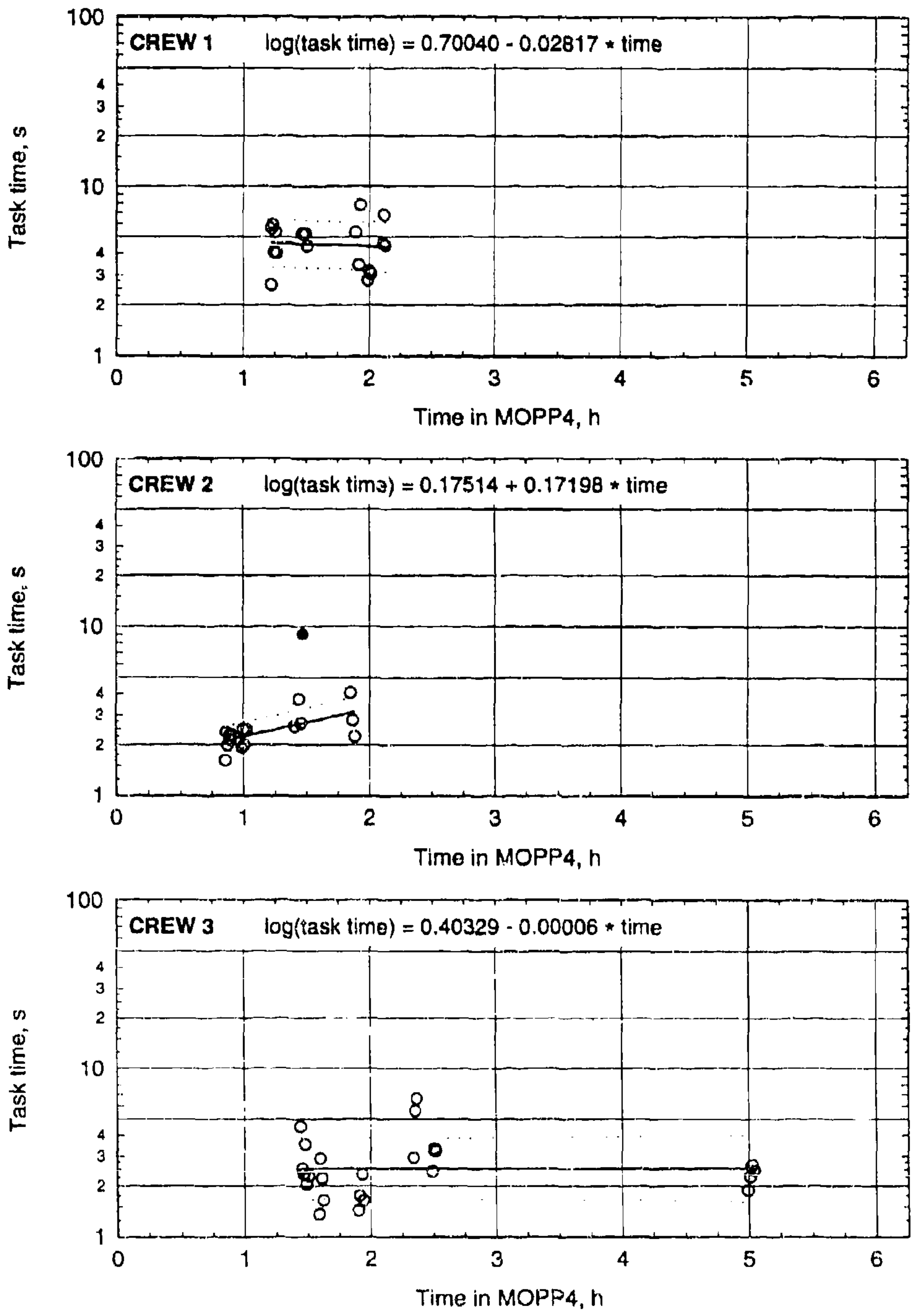


Figure C-75. Task times with regression lines for **fire** in MOPP4-S.

FIRE, ALL CREWS: MOPP4 - STANDARD
(Linear regression with 68 % confidence band)

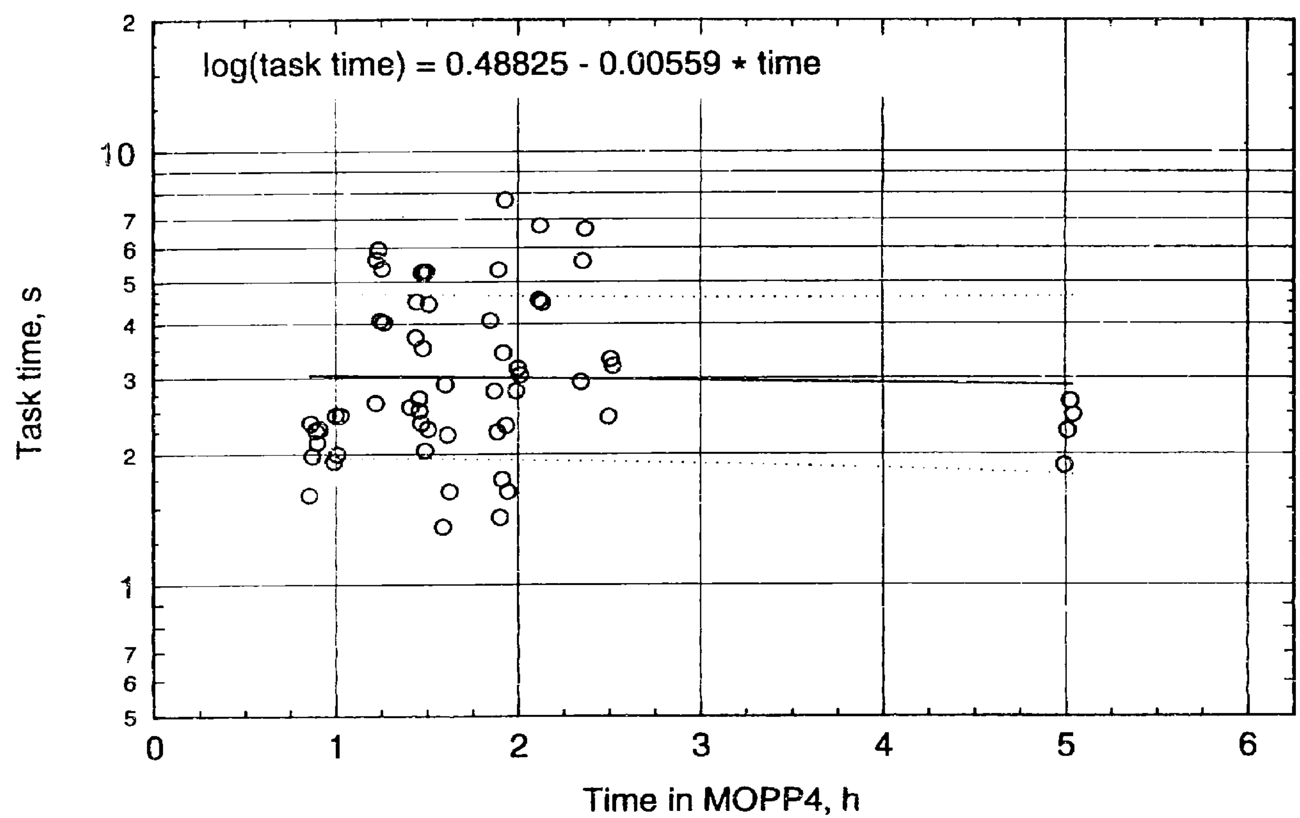


Figure C-76. Aggregate task time data with regression line for **fire** in MOPP4-S.

Table C-75. Statistical summary[1] for **fire** with crews in MOPP4-S.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	.65370	.38163	.40315	.47800
Number of Observations	19	16	24	59
Total Sum of Squares	.30244	.15409	.67575	2.00191
Residual Sum of Squares	.30057	.08727	.67575	2.00018
Std. Dev. of Estimate	.13297	.07895	.17526	.18733
R-squared	.00618	.43362	.00000	.00086
Adjusted R-squared	-.05228	.39316	-.04545	-.01667
Degrees of Freedom (df)	17	14	22	57
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	.10578	10.71823	.00000	.04927
Prob. Value of F	.74896	.00554	.99842	.82513
Constant	.70040	.17514	.40329	.48825
Standard error	.14680	.06609	.07865	.05224
Slope	-.02817	.17198	-.00006	-.00559
Standard error	.08662	.05253	.02918	.02517
t-ratio	-.32525	3.27387	-.00200	-.22197
prob t	.74896	.00554	.99842	.82513
Correlation Coefficient	-.07864	.65850	-.00043	-.02939

[1]See Section 4 for discussion of regression equations and units.

Table C-76. ANOVA for **fire** with crews in MOPP4-S.

	Sum Sq	*DF*	*Mean Sq*
Crew	.86962	2	1.13229
Error	.43481	56	.02022

Mean of Dependent Variable	.47800
Number of Observations	59
Total Sum of Squares	2.00191
Residual Sum of Squares	1.13229
Std. Dev. of Estimate	.14220
R-squared	.43440
Adjusted R-squared	.41420
Degrees of Freedom (df)	56
Number of Ind Vars (K)	3
F(K-1, df)	21.50462
Prob. Value of F	.00000

FIRE: MOPP4 - ROTATING

(Linear regression with 68 % confidence band)

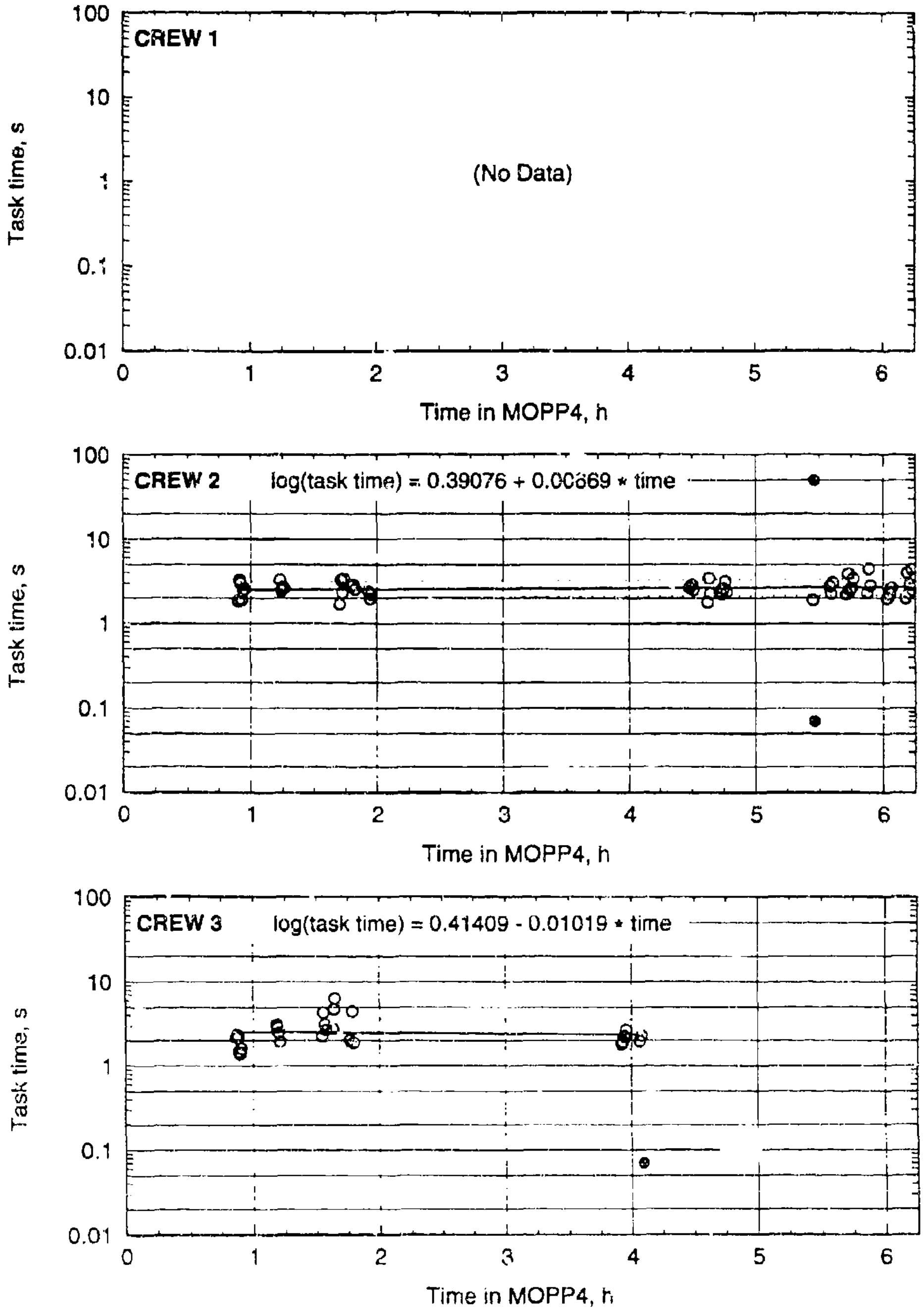


Figure C-77. Task times with regression lines for **fire** in MOPP4-R.

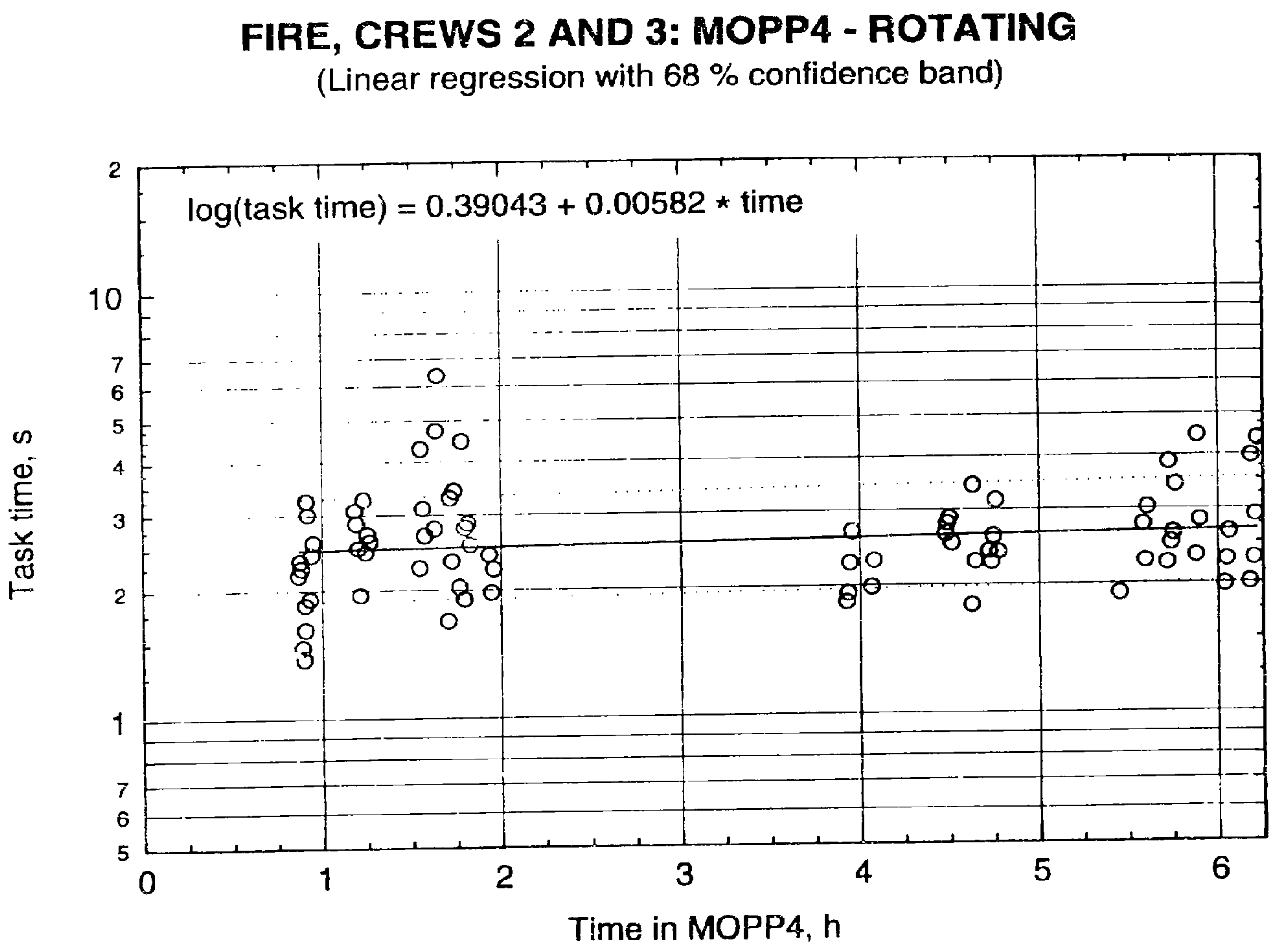


Figure C-78. Aggregate task time data with regression line for **fire** in MOPP4-R.

Table C-77. Statistical summary[1] for **fire** with crews in MOPP4-R.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	No Data	.41676	.39431	.40928
Number of Observations		52	26	78
Total Sum of Squares		.46063	.62761	1.09698
Residual Sum of Squares		.45116	.62399	1.08640
Std. Dev. of Estimate		.09499	.16124	.11956
R-squared		.02058	.00577	.00965
Adjusted R-squared		.00099	-.03565	-.00339
Degrees of Freedom (df)		50	24	76
Number of Ind Vars (K)		2	2	2
F(K-1, df)		1.05044	.13937	.74018
Prob. Value of F		.31034	.71219	.39231
Constant		.39076	.41409	.39043
Standard error		.02859	.06170	.02576
Slope		.00669	-.01019	.00582
Standard error		.00653	.02729	.00677
t-ratio		1.02491	-.37332	.86034
prob t		.31034	.71219	.39231
Correlation Coefficient		.14345	-.07598	.09821

[1]See Section 4 for discussion of regression equations and units.

Table C-78. ANOVA for **fire** with crews in MOPP4-R.

	Sum Sq	*DF*	*Mean Sq*
Crew	.00874	1	1.08825
Error	.00874	76	.01432

Mean of Dependent Variable	.40928
Number of Observations	78
Total Sum of Squares	1.09698
Residual Sum of Squares	1.08825
Std. Dev. of Estimate	.11966
R-squared	.00796
Adjusted R-squared	-.00509
Degrees of Freedom (df)	76
Number of Ind Vars (K)	2
F(K-1, df)	.61003
Prob. Value of F	.43720

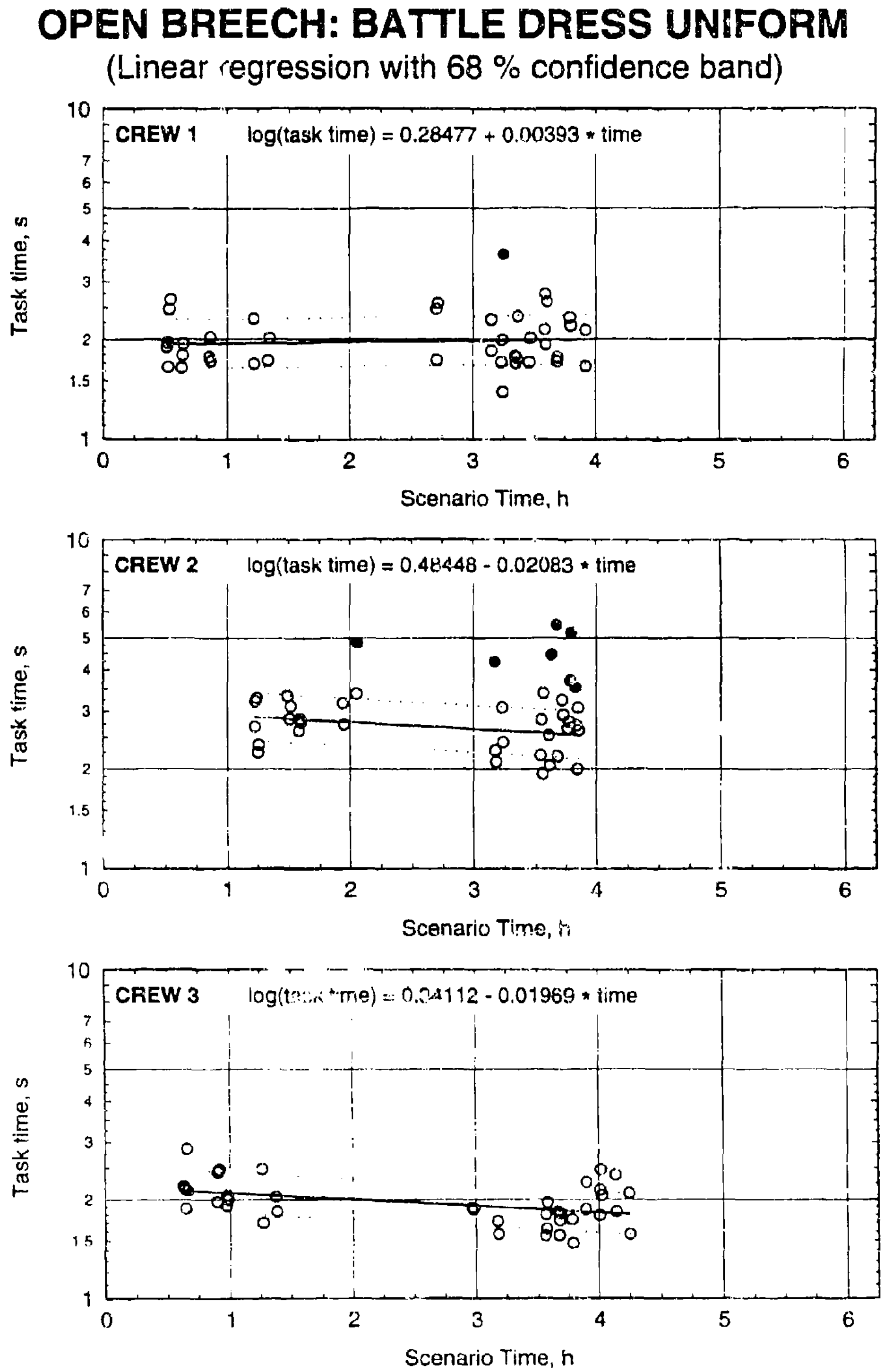


Figure C-79. Task times with regression lines for **open breech** in BDU.

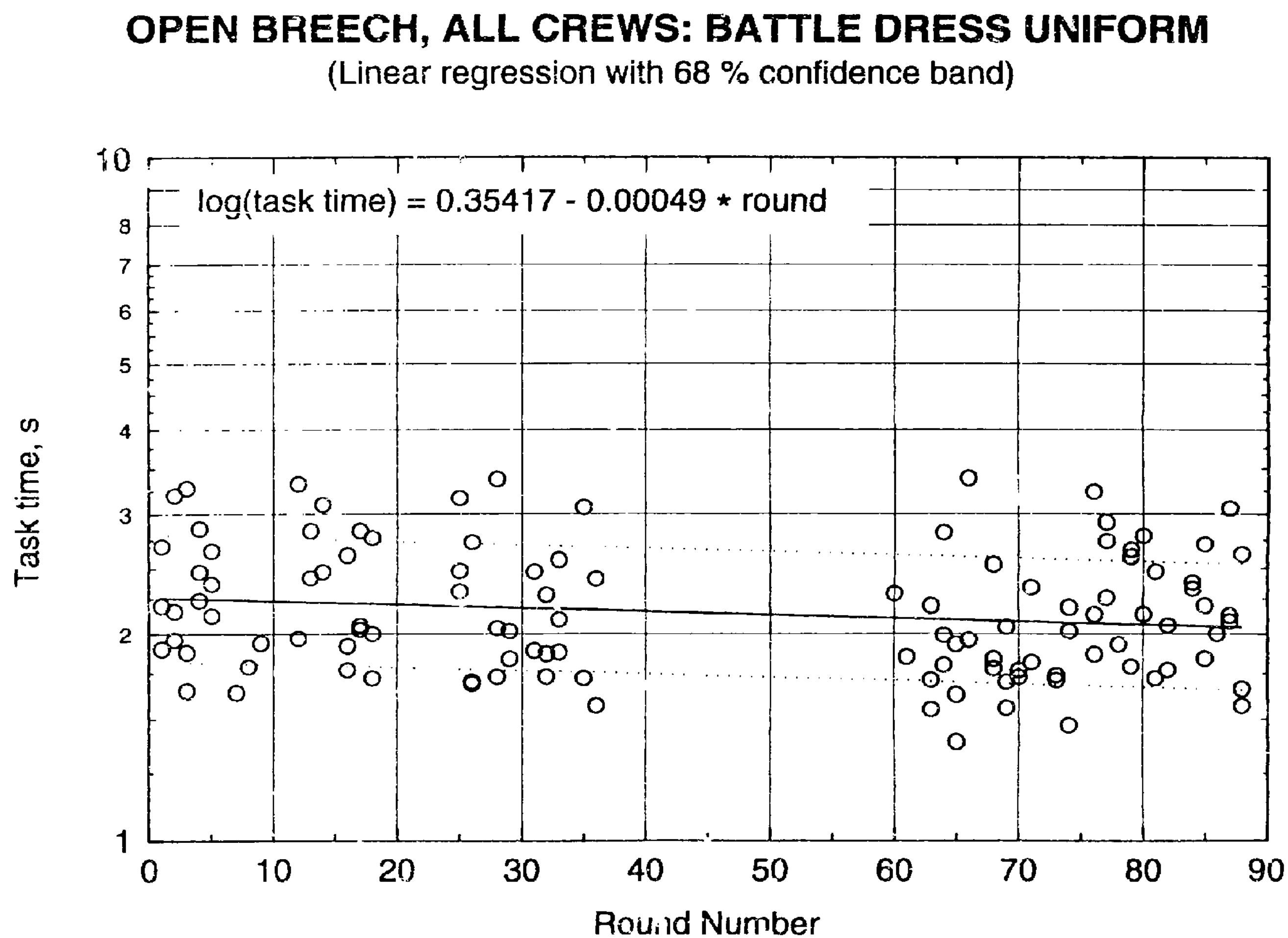


Figure C-80. Aggregate task time data with regression line for **open breech** in BDU.

Table C-79. Statistical summary[1] for **open breech** with crews in BDU.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	.29424	.42785	.28863	.33160
Number of Observations	39	33	40	112
Total Sum of Squares	.19080	.16287	.16699	.95464
Residual Sum of Squares	.18978	.14710	.13767	.93027
Std. Dev. of Estimate	.07162	.06889	.06019	.09196
R-squared	.00533	.09680	.17561	.02553
Adjusted R-squared	-.02156	.06767	.15391	.01667
Degrees of Freedom (df)	37	31	38	110
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	.19814	3.32247	8.09441	2.88166
Prob. Value of F	.65882	.07800	.00712	.09242
Constant	.28477	.48448	.34112	.35417
Standard error	.02416	.03331	.02076	.01588
Slope	.00393	-.02083	-.01969	-.00049
Standard error	.00883	.01143	.00692	.00029
t-ratio	.44512	-1.82276	-2.84507	-1.69754
prob t	.65882	.07800	.00712	.09242
Correlation Coefficient	.07298	-.31113	-.41905	-.15978

[1]See Section 4 for discussion of regression equations and units.

Table C-80. ANOVA for **open breech** with crews in BDU.

	Sum Sq	*DF*	*Mean Sq*
Crew	.43398	2	.52066
Error	.21699	109	.00478

Mean of Dependent Variable	.33160
Number of Observations	112
Total Sum of Squares	.95464
Residual Sum of Squares	.52066
Std. Dev. of Estimate	.06911
R-squared	.45460
Adjusted R-squared	.44460
Degrees of Freedom (df)	109
Number of Ind Vars (K)	3
F(K-1, df)	45.42738
Prob. Value of F	.00000

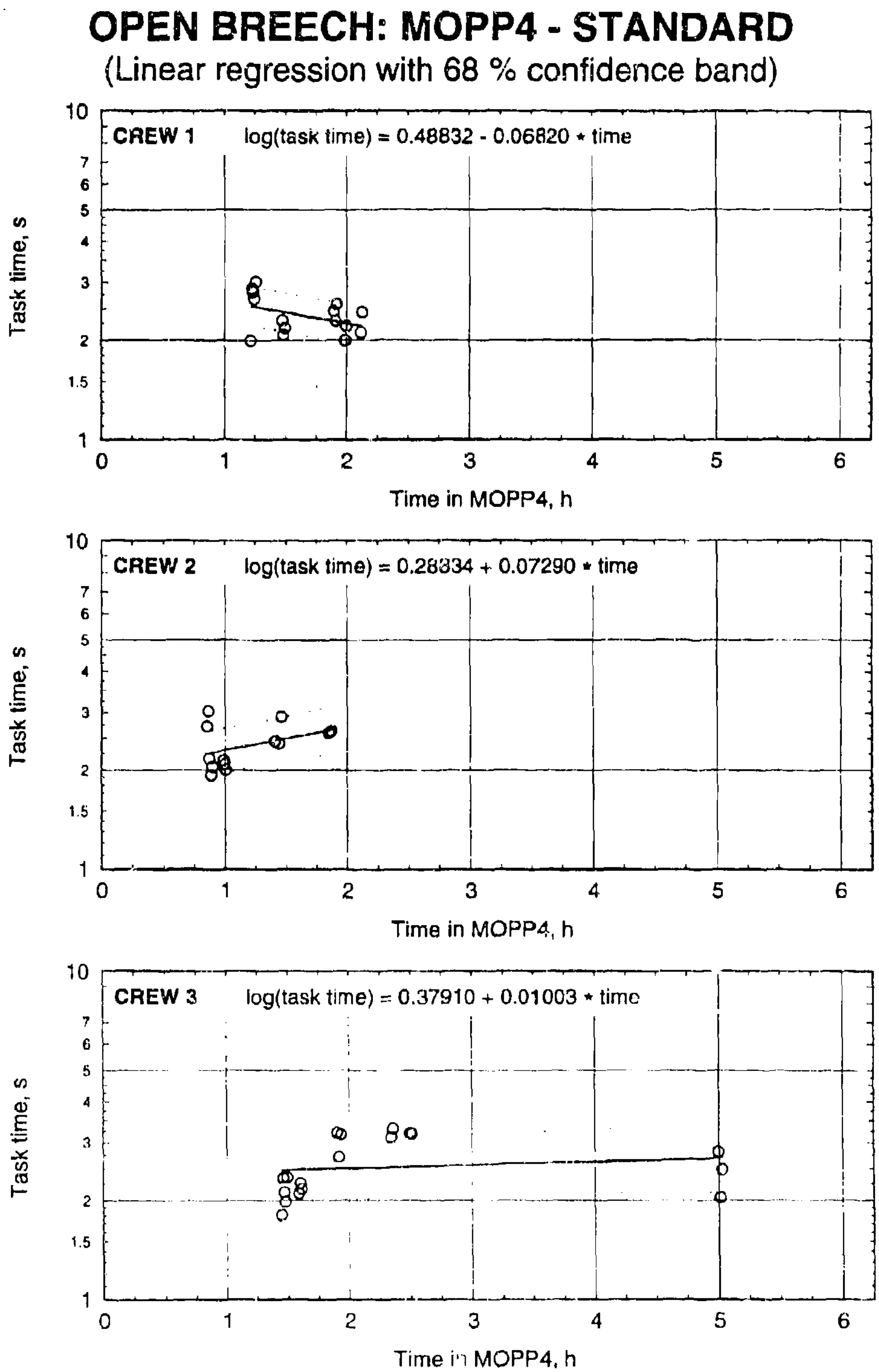


Figure C-81. Task times with regression lines for **open breech** in MOPP4-S.

OPEN BREECH, ALL CREWS: MOPP4 - STANDARD

(Linear regression with 68 % confidence band)

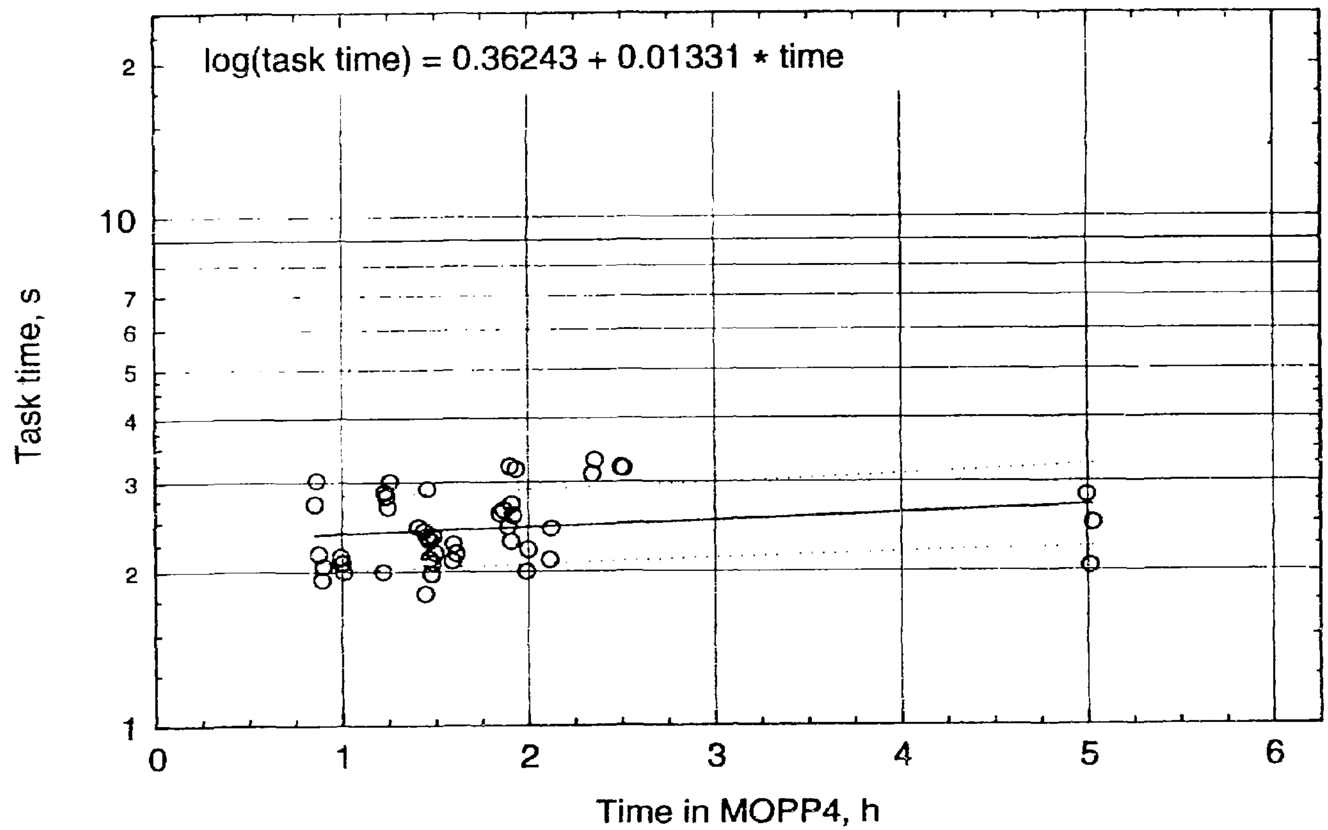


Figure C-82. Aggregate task time data with regression line for **open breech** in MOPP4-S.

Table C-81. Statistical summary[1] for **open breech** with crews in MOPP4-S.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	.37657	.37469	.40285	.38632
Number of Observations	15	13	18	46
Total Sum of Squares	.04690	.05099	.12876	.23476
Residual Sum of Squares	.03848	.04207	.12600	.22731
Std. Dev. of Estimate	.05440	.06185	.08874	.07188
R-squared	.17967	.17477	.02144	.03172
Adjusted R-squared	.11656	.09975	-.03971	.00971
Degrees of Freedom (df)	13	11	16	44
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	2.84719	2.32958	.35064	1.44146
Prob. Value of F	.11537	.15516	.56203	.23633
Constant	.48832	.28834	.37910	.36243
Standard error	.06770	.05912	.04523	.02255
Slope	-.06820	.07290	.01003	.01331
Standard error	.04042	.04776	.01694	.01108
t-ratio	-1.68736	1.52630	.59215	1.20061
prob t	.11537	.15516	.56203	.23633
Correlation Coefficient	-.42387	.41805	.14644	.17810

[1]See Section 4 for discussion of regression equations and units.

Table C-82. ANOVA for **open breech** with crews in MOPP4-S.

	Sum Sq	*DF*	*Mean Sq*
Crew	.00810	2	.22665
Error	.00405	43	.00527

Mean of Dependent Variable	.38632
Number of Observations	46
Total Sum of Squares	.23476
Residual Sum of Squares	.22665
Std. Dev. of Estimate	.07260
R-squared	.03452
Adjusted R-squared	-.01038
Degrees of Freedom (df)	43
Number of Ind Vars (K)	3
F(K-1, df)	.76881
Prob. Value of F	.46983

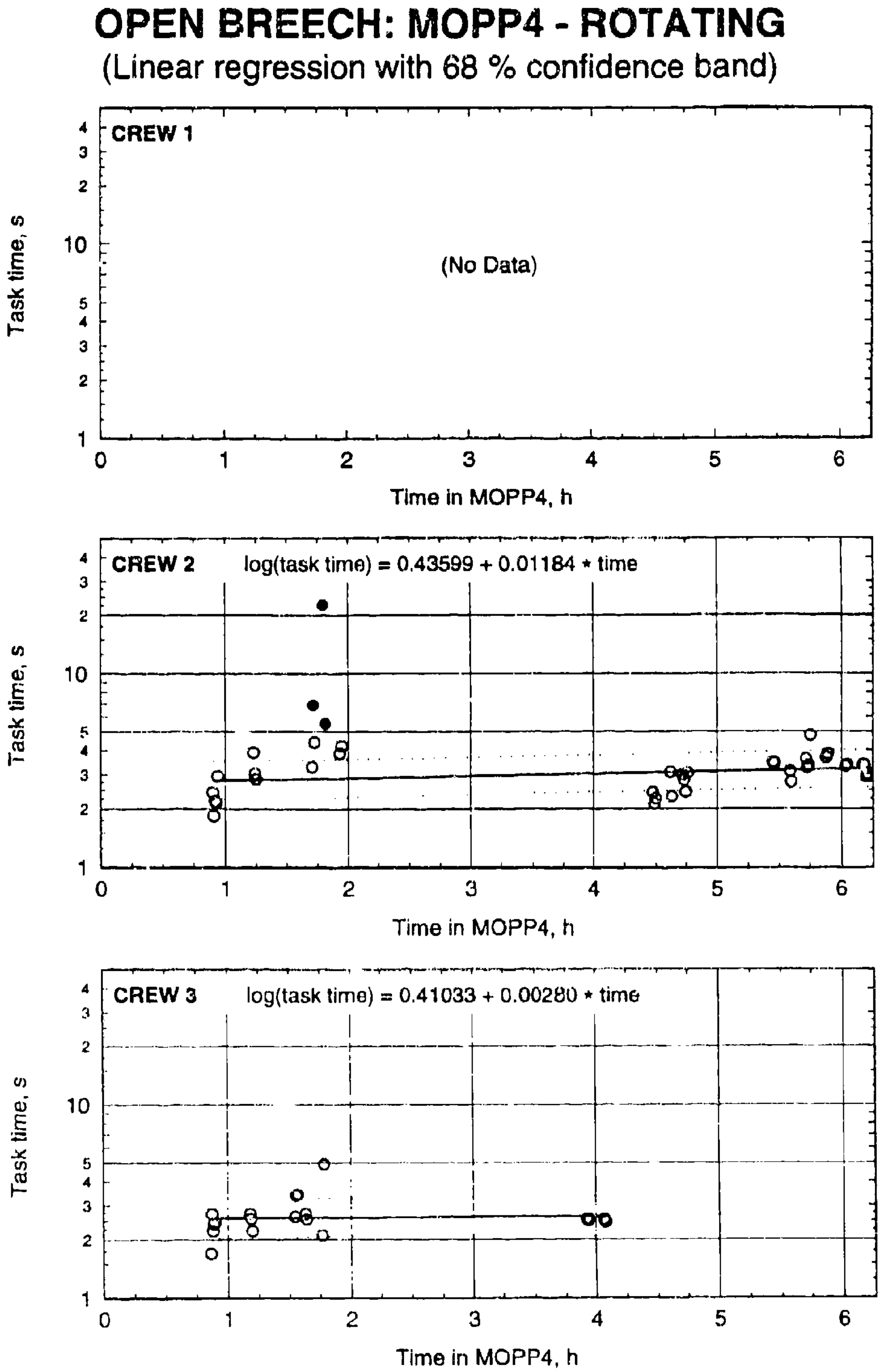


Figure C-83. Task times with regression lines for **open breech** in MOPP4-R.

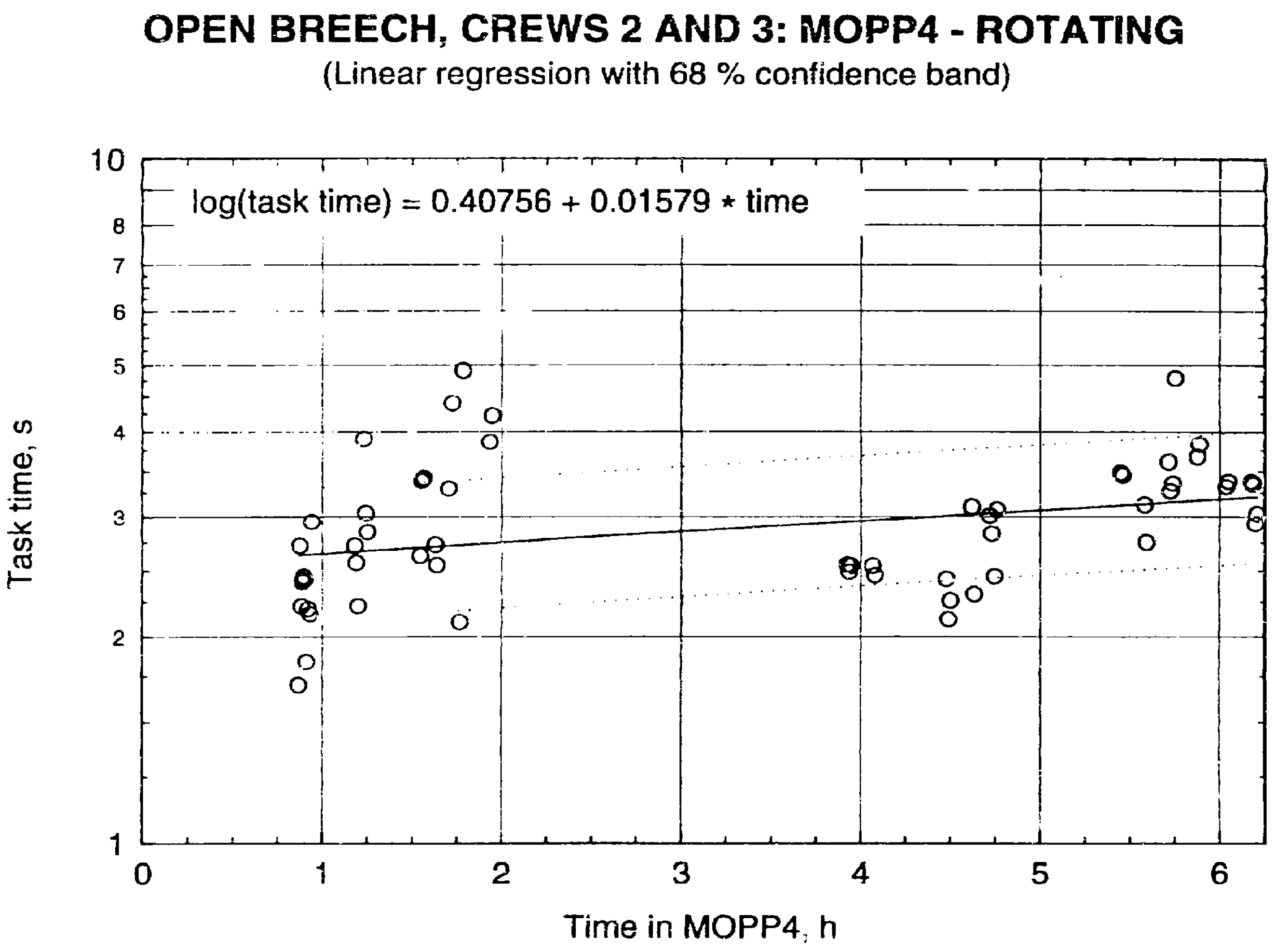


Figure C-84. Aggregate task time data with regression line for **open breech** in MOPP4-R.

Table C-83. Statistical summary[1] for **open breech** with crews in MOPP4-R.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	No Data	.48430	.41585	.46028
Number of Observations		37	20	57
Total Sum of Squares		.32451	.16004	.54539
Residual Sum of Squares		.30367	.15981	.48671
Std. Dev. of Estimate		.09315	.09423	.09407
R-squared		.06423	.00142	.10759
Adjusted R-squared		.03750	-.05406	.09137
Degrees of Freedom (df)		35	18	55
Number of Ind Vars (K)		2	2	2
F(K-1, df)		2.40246	.02558	6.63097
Prob. Value of F		.13014	.87471	.01274
Constant		.43599	.41033	.40756
Standard error		.03473	.04041	.02397
Slope		.01184	.00280	.01579
Standard error		.00764	.01751	.00613
t-ratio		1.54999	.15993	2.57507
prob t		.13014	.87471	.01274
Correlation Coefficient		.25544	.03767	.32801

[1]See Section 4 for discussion of regression equations and units.

Table C-84. ANOVA for **open breech** with crews in MOPP4-R.

	Sum Sq	*DF*	*Mean Sq*
Crew	.06034	1	.48455
Error	.06084	55	.00881

Mean of Dependent Variable	.46028
Number of Observations	57
Total Sum of Squares	.54539
Residual Sum of Squares	.48455
Std. Dev. of Estimate	.09386
R-squared	.11155
Adjusted R-squared	.09540
Degrees of Freedom (df)	55
Number of Ind Vars (K)	2
F(K-1, df)	6.90591
Prob. Value of F	.01111

SWAB CHAMBER: BATTLE DRESS UNIFORM

(Linear regression with 68 % confidence band)

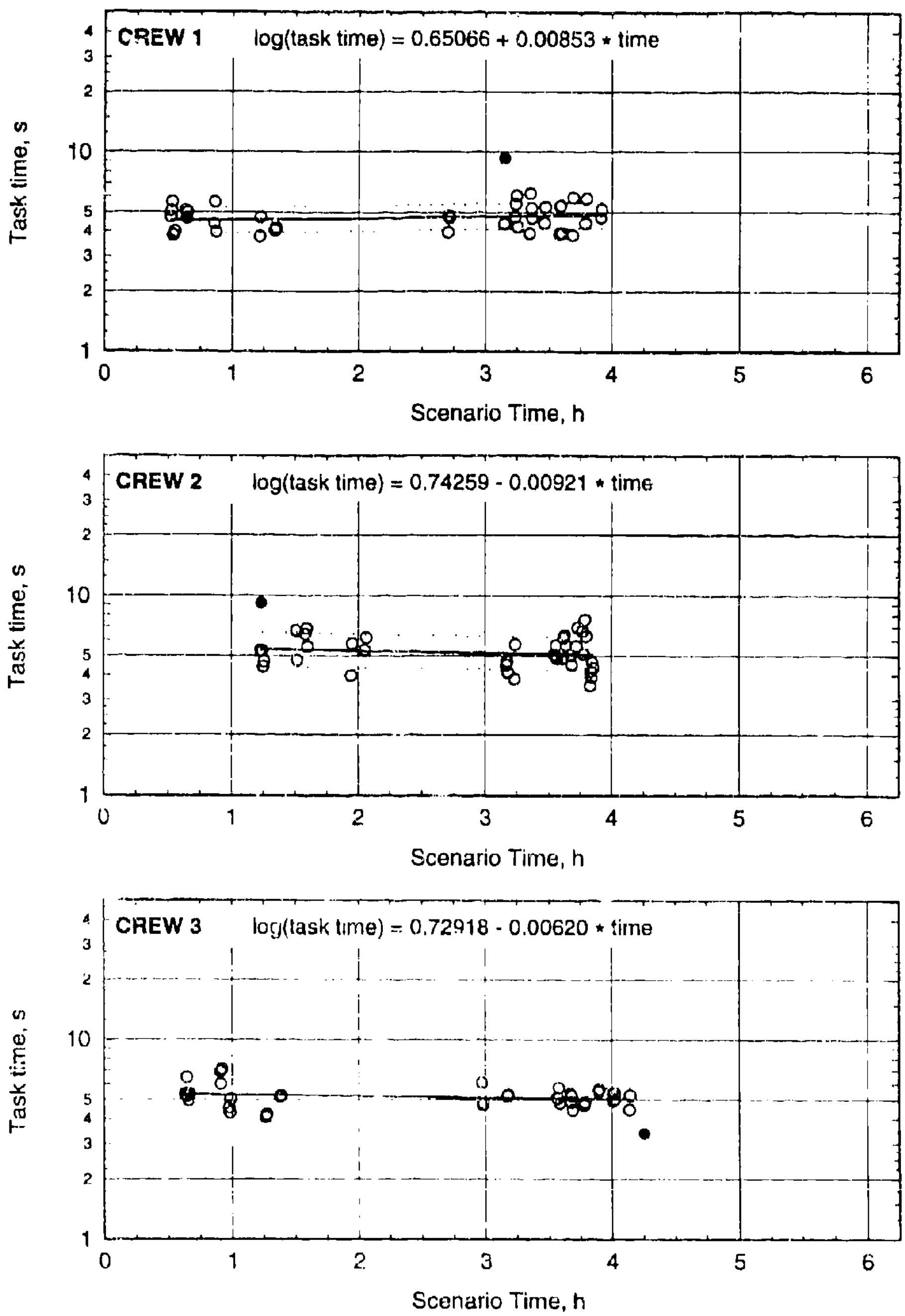


Figure C-85. Task times with regression lines for **swab chamber** in BDU.

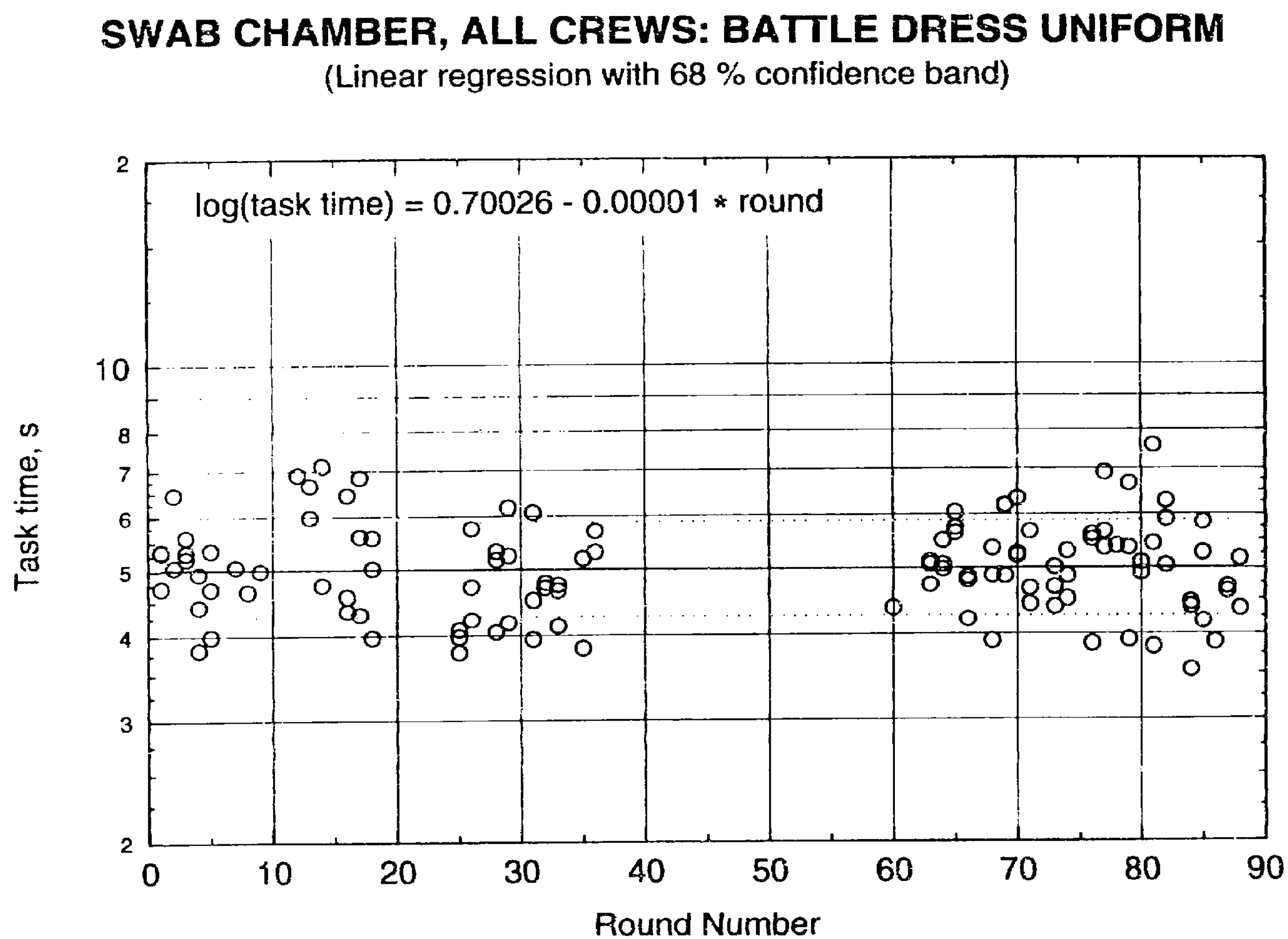


Figure C-86. Aggregate task time data with regression line for **swab chamber** in BDU.

Table C-85. Statistical summary[1] for **swab chamber** with crews in BDU.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	.67123	.71553	.71315	.69986
Number of Observations	39	3[illegible]	38	116
Total Sum of Squares	.15082	.24415	.10394	.54717
Residual Sum of Squares	.14603	.24097	.10123	.54716
Std. Dev. of Estimate	.06282	.08070	.05303	.06928
R-squared	.03180	.01301	.02604	.00001
Adjusted R-squared	.00564	-.01367	-.00102	-.00876
Degrees of Freedom (df)	37	37	36	114
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	1.21541	.48761	.96239	.00150
Prob. Value of F	.27738	.48936	.33313	.96921
Constant	.65066	.74259	.72918	.70026
Standard error	.02120	.04085	.01846	.01215
Slope	.00853	-.00921	-.00620	-.00001
Standard error	.00774	.01318	.00632	.00022
t-ratio	1.10246	-.69829	-.98102	-.03869
prob t	.27738	.48936	.33313	.96921
Correlation Coefficient	.17834	-.11405	-.16136	-.00362

[1] See Section 4 for discussion of regression equations [illegible] units.

Table C-86. ANOVA for **swab chamber** with crews in BDU.

	Sum Sq	*DF*	*Mean Sq*
Crew	.04826	2	.49891
Error	.02413	113	.00442

Mean of Dependent Variable	.69986
Number of Observations	116
Total Sum of Squares	.54717
Residual Sum of Squares	.49891
Std Dev. of Estimate	.06645
R-squared	.08820
Adjusted R-squared	.07206
Degrees of Freedom (df)	113
Number of Ind Vars (K)	3
F(K-1, df)	5.46504
Prob. Value of F	00543

SWAB CHAMBER: MOPP4 - STANDARD
(Linear regression with 68 % confidence band)

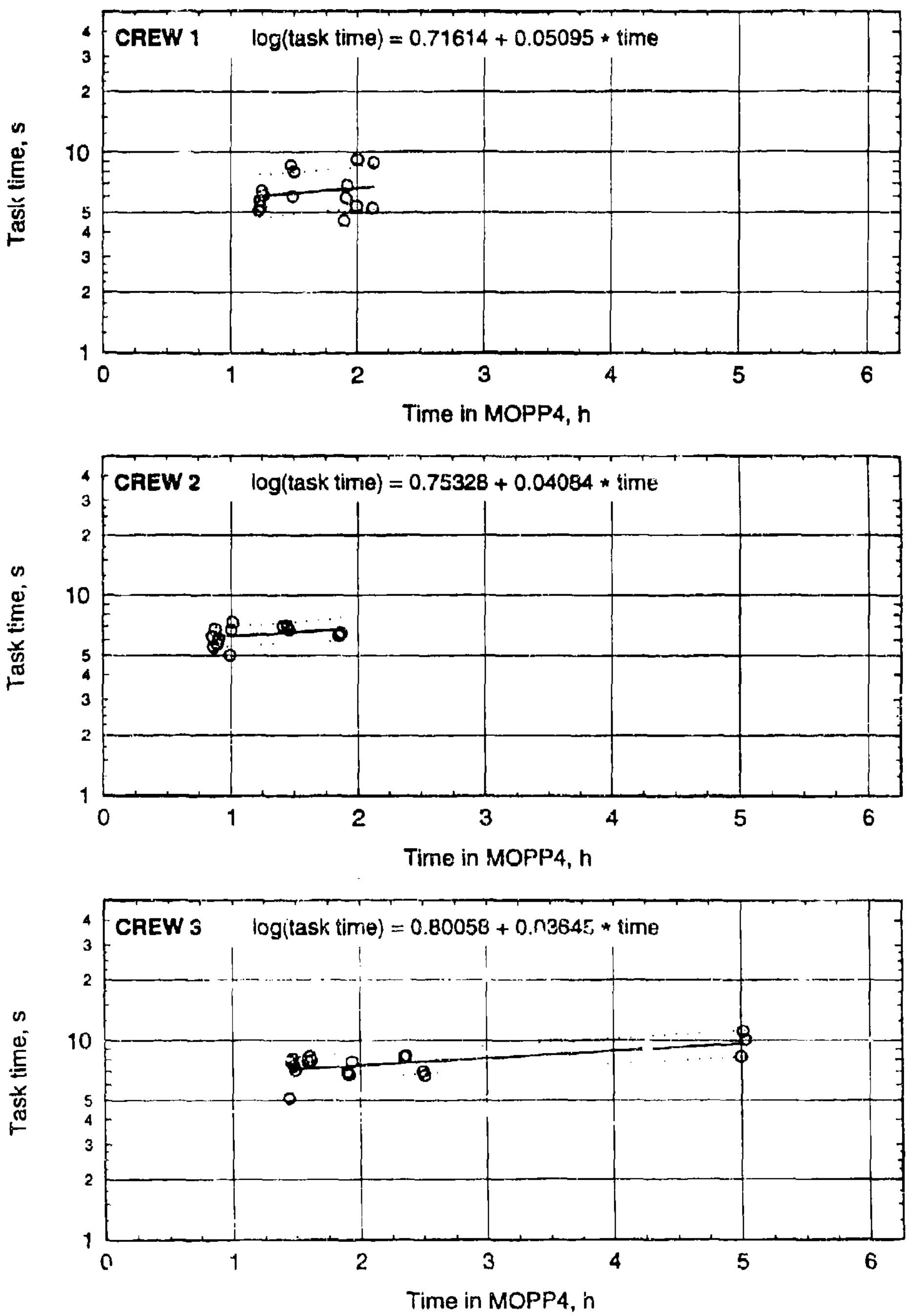


Figure C-87. Task times with regression lines for **swab chamber** in MOPP4-S.

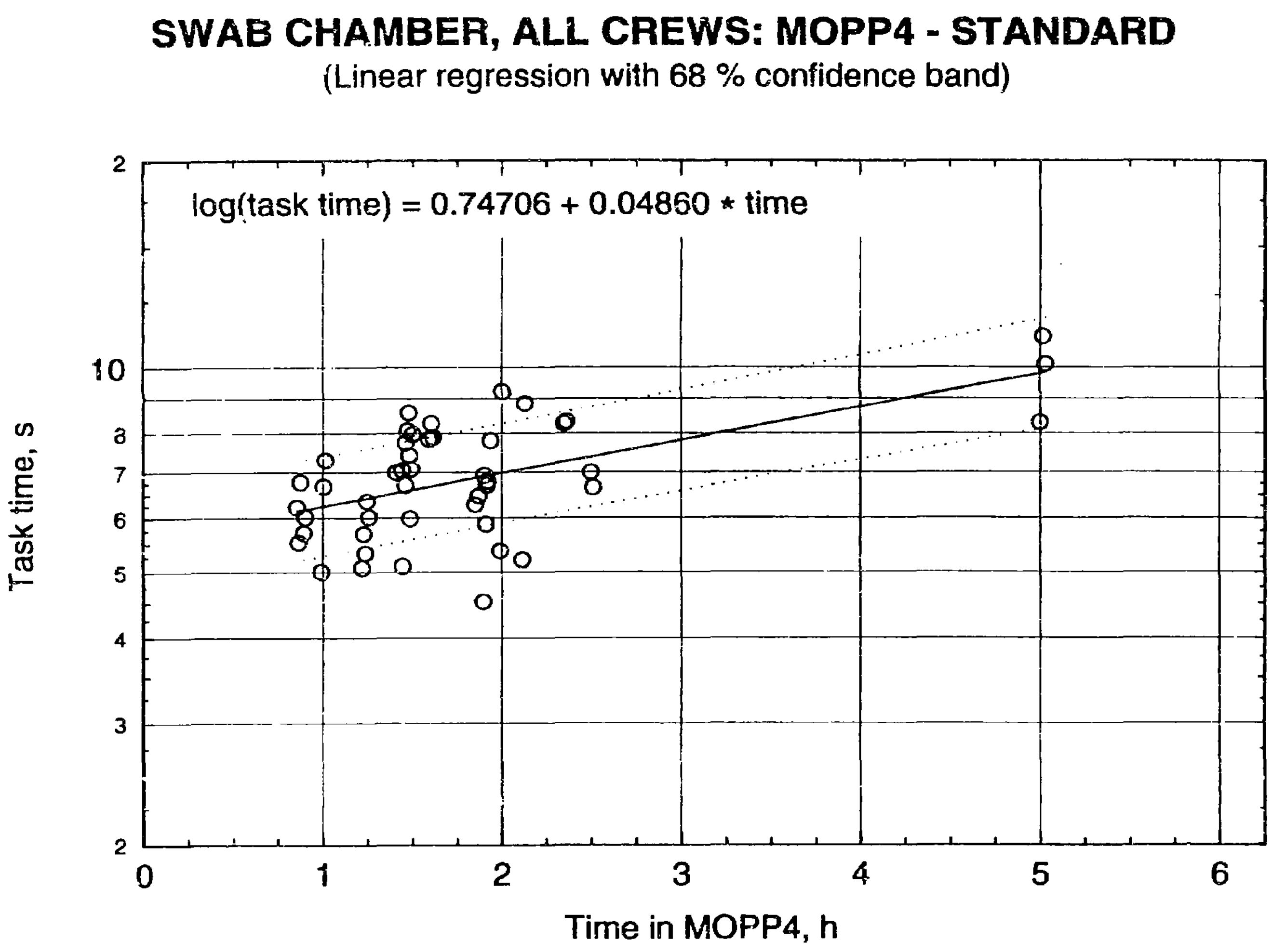


Figure C-88. Aggregate task time data with regression line for **swab chamber** in MOPP4-S.

Table C-87. Statistical summary[1] for **swab chamber** with crews in MOPP4-S.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	.79976	.80175	.88701	.83446
Number of Observations	15	13	18	46
Total Sum of Squares	.12854	.02650	.08861	.32533
Residual Sum of Squares	.12384	.02370	.05212	.22593
Std. Dev. of Estimate	.09760	.04642	.05708	.07166
R-squared	.03660	.10557	.41179	.30553
Adjusted R-squared	-.03751	.02426	.37503	.28975
Degrees of Freedom (df)	13	11	16	44
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	.49388	1.29835	11.20122	19.35782
Prob. Value of F	.49459	.27872	.00409	.00007
Constant	.71614	.75328	.80058	.74706
Standard error	.12162	.04444	.02912	.02250
Slope	.05095	.04084	.03645	.04860
Standard error	.07250	.03584	.01089	.01105
t-ratio	.70277	1.13945	3.34682	4.39975
prob t	.49459	.27872	.00409	.00007
Correlation Coefficient	.19131	.32492	.64171	.55275

[1]See Section 4 for discussion of regression equations and units.

Table C-88. ANOVA for **swab chamber** with crews in MOPP4-S.

	Sum Sq	*DF*	*Mean Sq*
Crew	.08168	2	.24365
Error	.04084	43	.00567

Mean of Dependent Variable	.83446
Number of Observations	46
Total Sum of Squares	.32533
Residual Sum of Squares	.24365
Std. Dev. of Estimate	.07528
R-squared	.25106
Adjusted R-squared	.21622
Degrees of Freedom (df)	43
Number of Ind Vars (K)	3
F(K-1, df)	7.20717
Prob. Value of F	.00200

SWAB CHAMBER: MOPP4 - ROTATING
(Linear regression with 68 % confidence band)

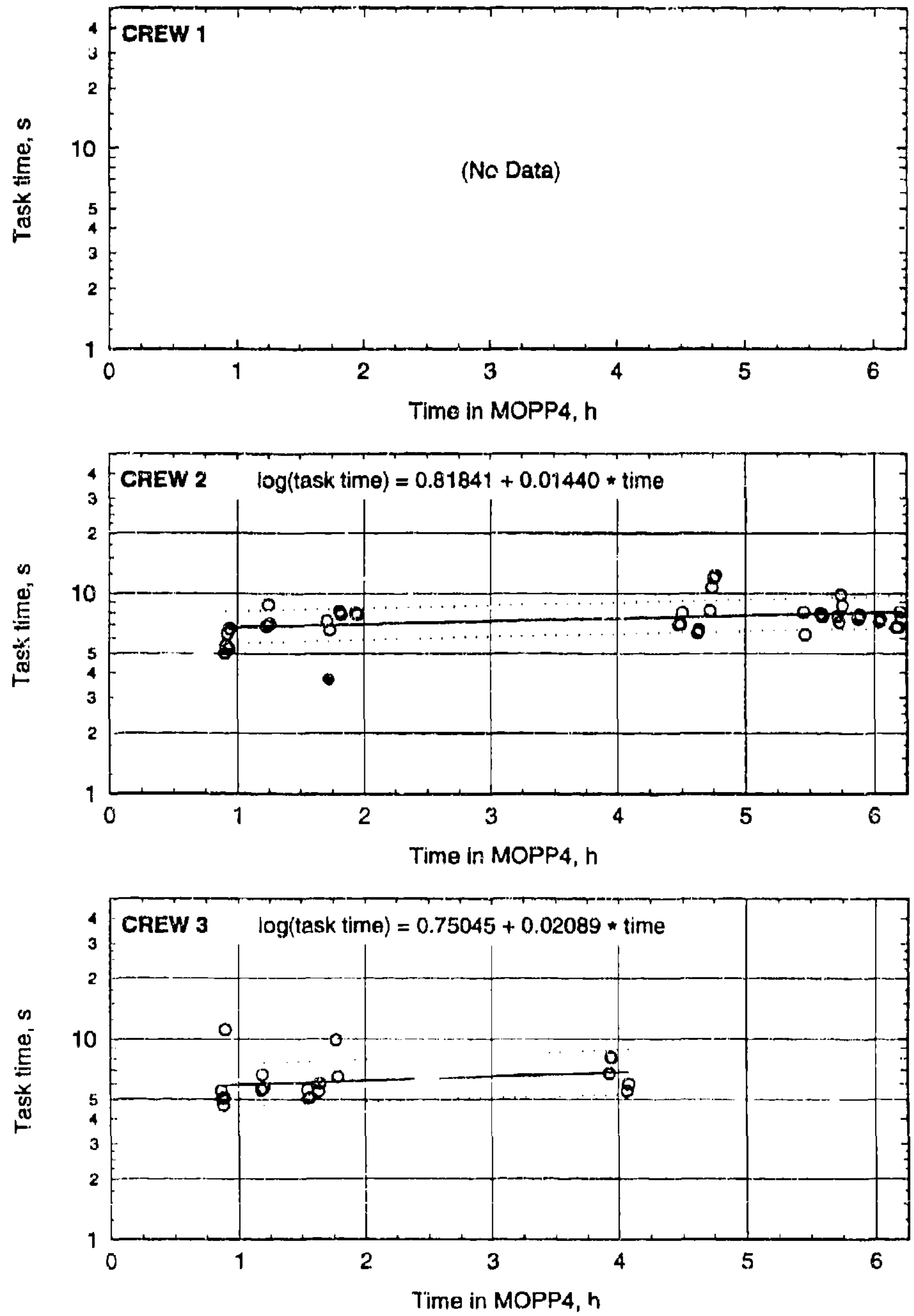


Figure C-89. Task times with regression lines for **swab chamber** in MOPP4-R.

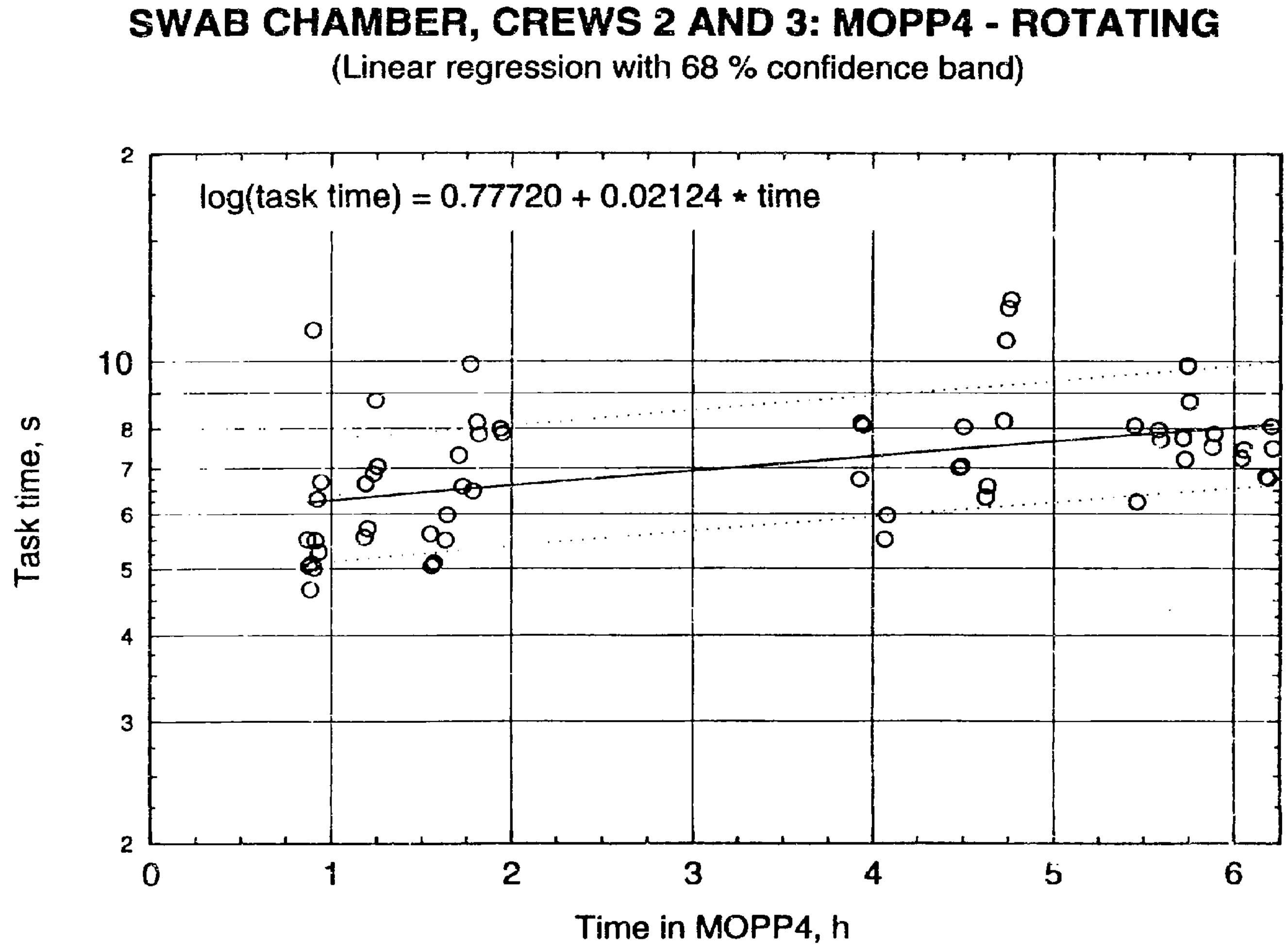


Figure C-90. Aggregate task time data with regression line for **swab chamber** in MOPP4-R.

Table C-89. Statistical summary[1] for **swab chamber** with crews in MOPP4-R.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	No Data	.87553	.79166	.84710
Number of Observations		39	20	59
Total Sum of Squares		.24923	.19465	.53687
Residual Sum of Squares		.21637	.18200	.42857
Std. Dev. of Estimate		.07647	.10055	.08671
R-squared		.13184	.06499	.20173
Adjusted R-squared		.10837	.01304	.18773
Degrees of Freedom (df)		37	18	57
Number of Ind Vars (K)		2	2	2
F(K-1, df)		5.61872	1.25105	14.40443
Prob. Value of F		.02309	.27806	.00036
Constant		.81841	.75045	.77720
Standard error		.02703	.04317	.02160
Slope		.01440	.02089	.02124
Standard error		.00607	.01868	.00560
t-ratio		2.37038	1.11850	3.79532
prob t		.02309	.27806	.00036
Correlation Coefficient		.36309	.25492	.44914

[1]See Section 4 for discussion of regression equations and units.

Table C-90. ANOVA for **swab chamber** with crews in MOPP4-R.

	Sum Sq	*DF*	*Mean Sq*
Crew	.09299	1	.44388
Error	.09299	57	.00779

Mean of Dependent Variable	.84710
Number of Observations	59
Total Sum of Squares	.53687
Residual Sum of Squares	.44388
Std. Dev. of Estimate	.08825
R-squared	.17321
Adjusted R-squared	.15871
Degrees of Freedom (df)	57
Number of Ind Vars (K)	2
F(K-1, df)	11.94156
Prob. Value of F	.00104

CHECK SIGHT: BATTLE DRESS UNIFORM
(Linear regression with 68 % confidence band)

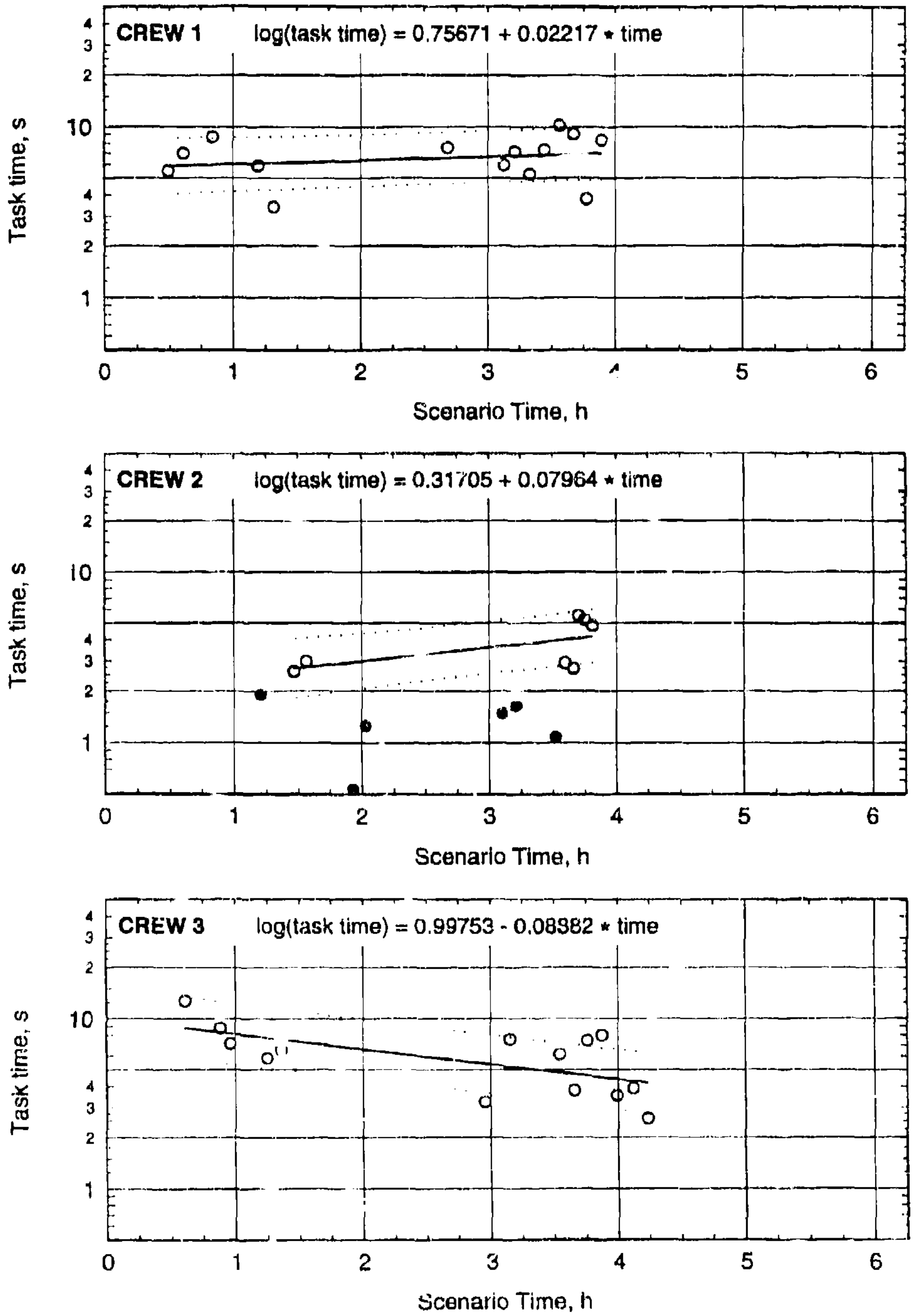


Figure C-91. Task times with regression lines for **check sight** in BDU.

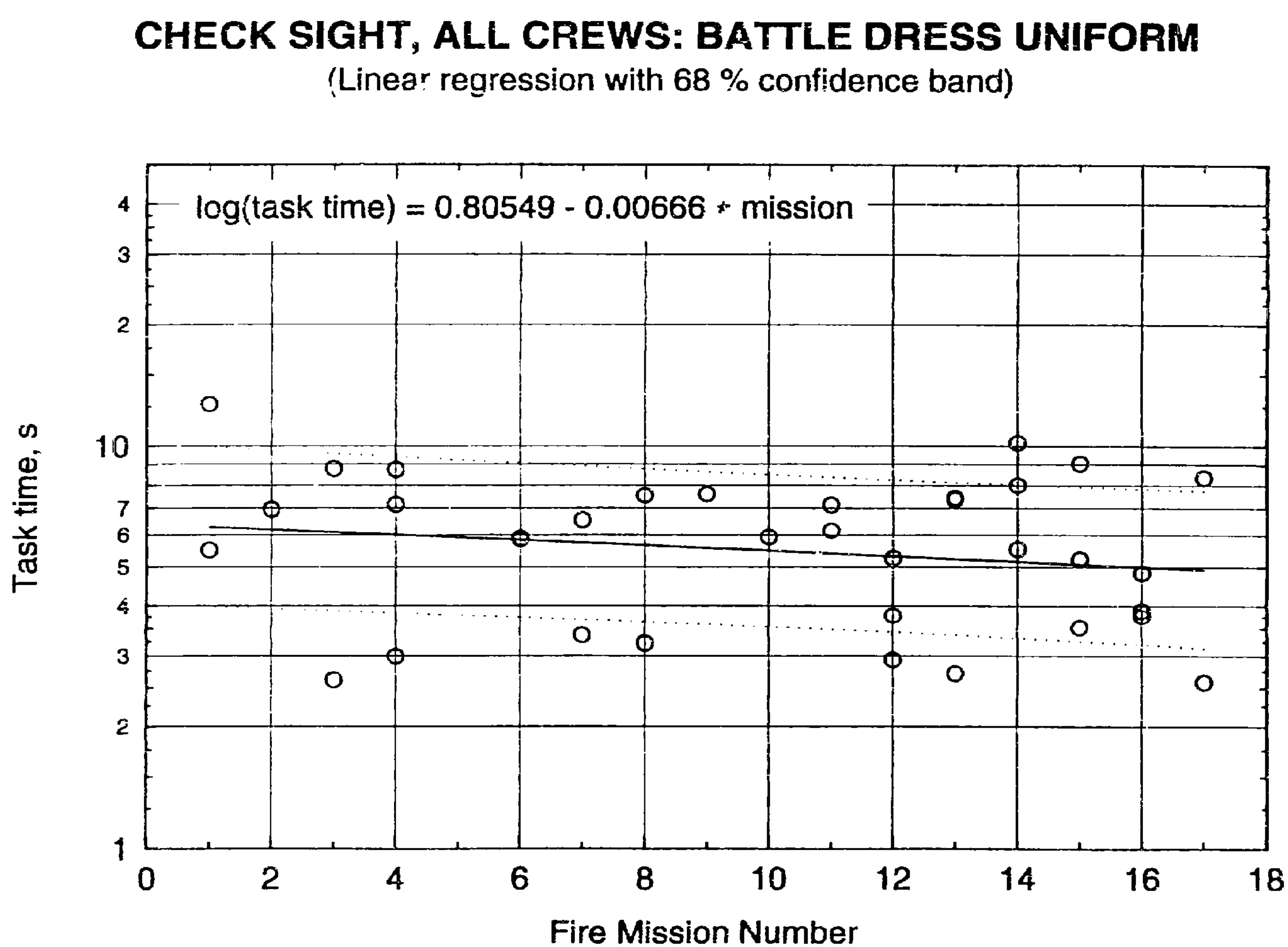


Figure C-92. Aggregate task time data with regression line for **check sight** in BDU.

Table C-91. Statistical summary[1] for **check sight** with crews in BDU.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	.81237	.56223	.75425	.73909
Number of Observations	14	7	14	35
Total Sum of Squares	.25118	.12583	.50433	1.17870
Residual Sum of Squares	.24038	.08229	.30697	1.14053
Std. Dev. of Estimate	.14153	.12829	.15994	.18591
R-squared	.04302	.34598	.39133	.03238
Adjusted R-squared	-.03673	.21517	.34060	.00306
Degrees of Freedom (df)	12	5	12	33
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	.53942	2.64498	7.71499	1.10445
Prob. Value of F	.47678	.16481	.01673	.30093
Constant	.75671	.31705	.99753	.80549
Standard error	.08469	.15836	.09746	.07056
Slope	.02217	.07964	-.08882	-.00666
Standard error	.03018	.04897	.03198	.00634
t-ratio	.73445	1.62634	-2.77759	-1.05093
prob t	.47678	.16481	.01673	.30093
Correlation Coefficient	.20741	.58820	-.62556	-.17996

[1]See Section 4 for discussion of regression equations and units.

Table C-92. ANOVA for **check sight** with crews in BDU.

	Sum Sq	*DF*	*Mean Sq*
Crew	.29736	2	.88134
Error	.14868	32	.02754

Mean of Dependent Variable	.73909
Number of Observations	35
Total Sum of Squares	1.17870
Residual Sum of Squares	.88134
Std. Dev. of Estimate	.16596
R-squared	.25228
Adjusted R-squared	.20554
Degrees of Freedom (df)	32
Number of Ind Vars (K)	3
F(K-1, df)	5.39826
Prob. Value of F	.00955

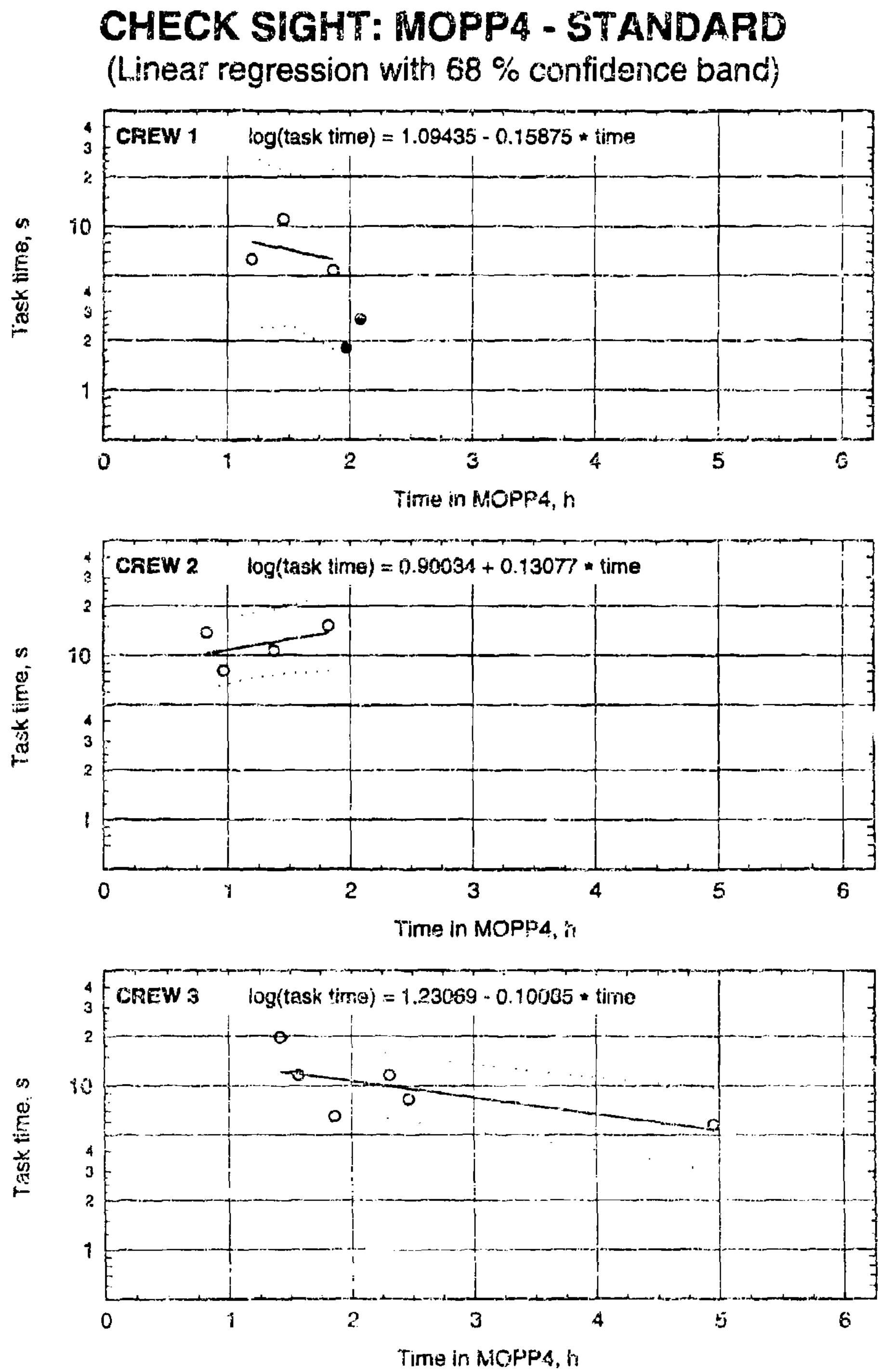


Figure C-93. Task times with regression lines for check sight in MOPP4-S.

CHECK SIGHT, ALL CREWS: MOPP4 - STANDARD

(Linear regression with 68 % confidence band)

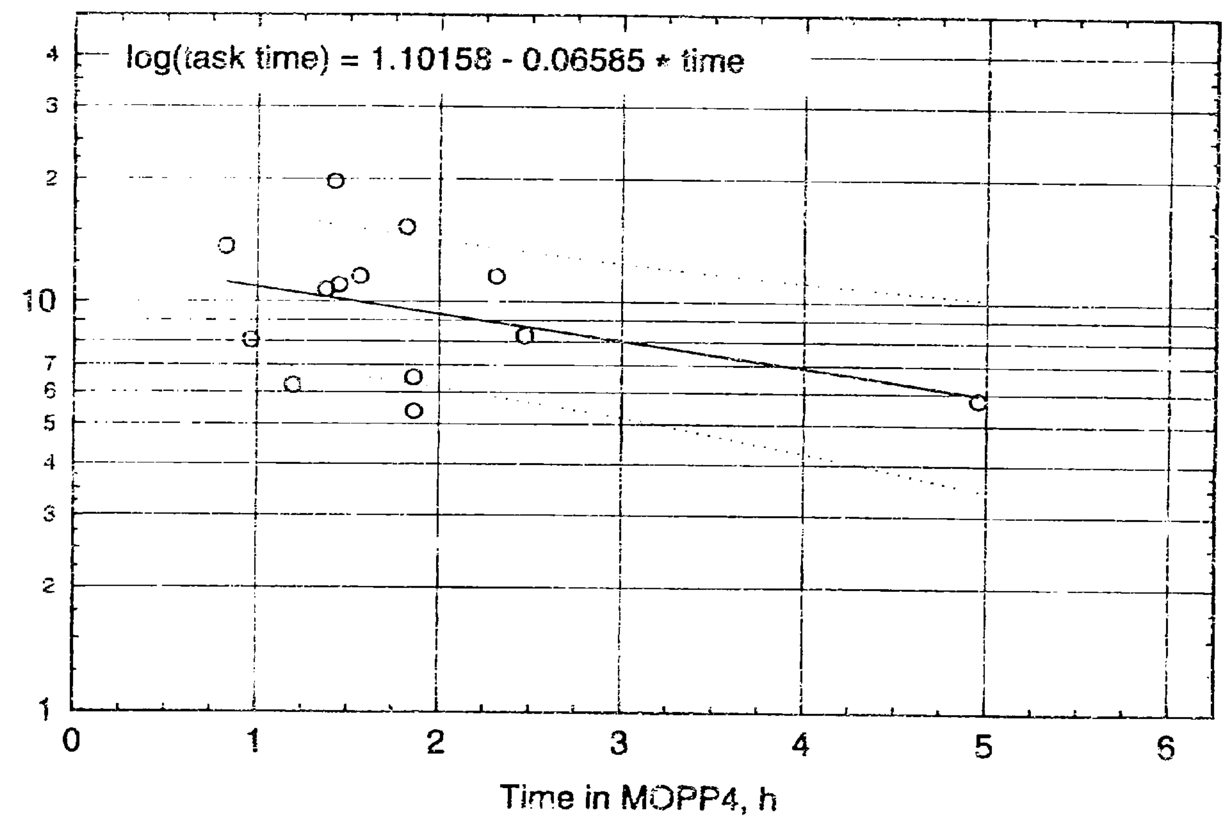


Figure C-94. Aggregate task time data with regression line for check sight in MOPP4-S.

Table C-93. Statistical summary[1] for **check sight** with crews in MOPP4-S.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	.85579	1.06344	.98564	.97961
Number of Observations	3	4	6	13
Total Sum of Squares	.05325	.04565	.19137	.36460
Residual Sum of Squares	.04757	.03542	.10509	.30762
Std. Dev. of Estimate	.21809	.13308	.16209	.16723
R-squared	.10684	.22408	.45085	.15628
Adjusted R-squared	-.78633	-.16389	.31357	.07958
Degrees of Freedom (df)	1	2	4	11
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	.11961	.57757	3.28403	2.03754
Prob. Value of F	.78802	.52663	.14418	.18122
Constant	1.09435	.90034	1.23069	1.10158
Standard error	.70117	.22469	.15055	.09722
Slope	-.15875	.13077	-.10085	-.06585
Standard error	.45902	.17206	.05565	.04613
t-ratio	-.34585	.75998	-1.81219	-1.42743
prob t	.78802	.52663	.14418	.18122
Correlation Coefficient	-.32686	.47337	-.67146	-.39533

[1]See Section 4 for discussion of regression equations and units.

Table C-94. ANOVA for **check sight** with crews in MOPP4-S.

	Sum Sq	*DF*	*Mean Sq*
Crew	.07432	2	.29027
Error	.03716	10	.02903

Mean of Dependent Variable	.97961
Number of Observations	13
Total Sum of Squares	.36460
Residual Sum of Squares	.29027
Std. Dev. of Estimate	.17037
R-squared	.20385
Adjusted R-squared	.04462
Degrees of Freedom (df)	10
Number of Ind Vars (K)	3
F(K-1, df)	1.28024
Prob. Value of F	.31987

CHECK SIGHT: MOPP4 - ROTATING
(Linear regression with 68 % confidence band)

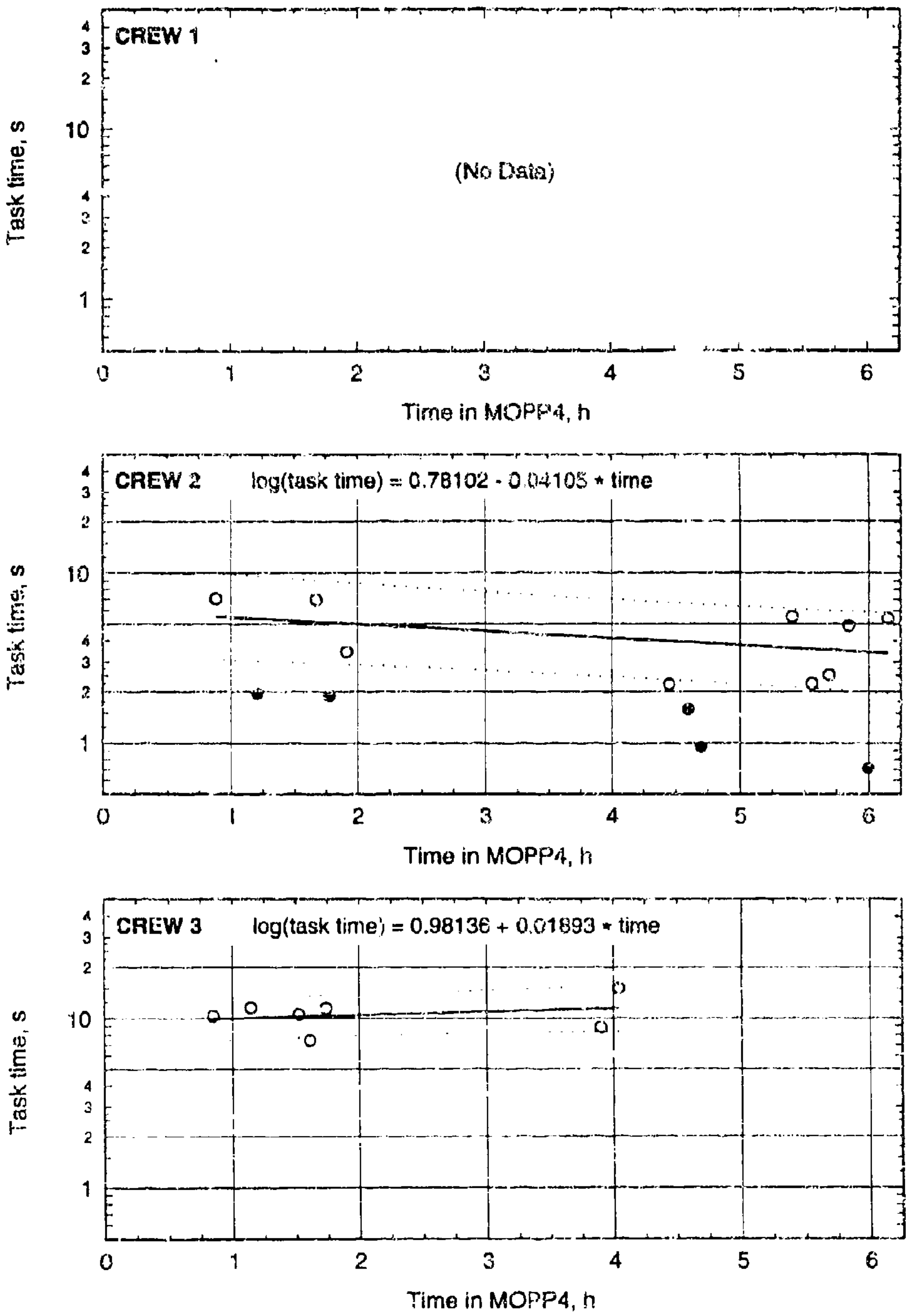


Figure C-95. Task times with regression lines for **check sight** in MOPP4-R.

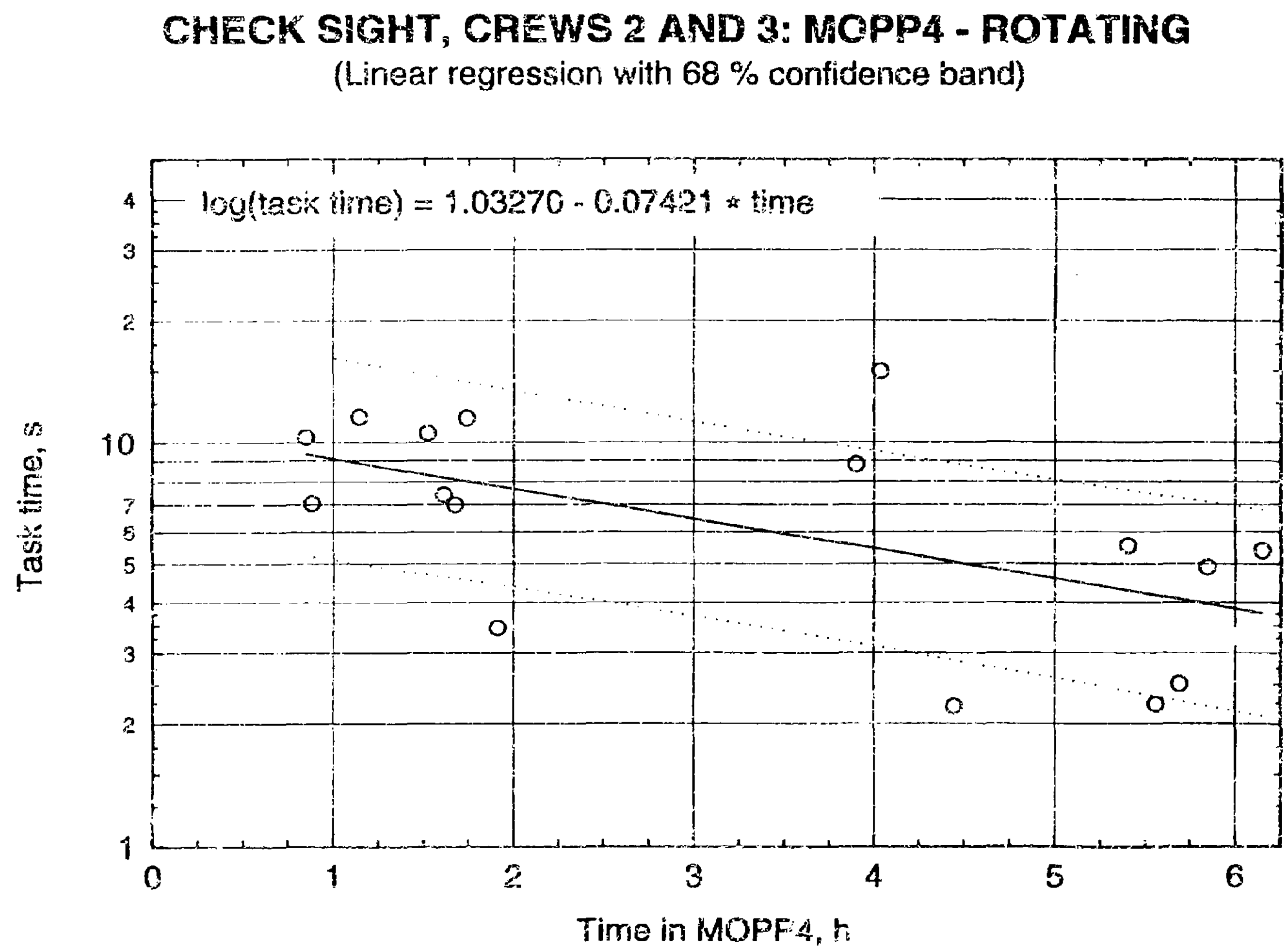


Figure C-96. Aggregate task time data with regression line for **check sight** in MOPP4-R.

Table C-95. Statistical summary[1] for **check sight** with crews in MOPP4-R.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	No Data	.60965	1.02137	.78978
Number of Observations		9	7	16
Total Sum of Squares		.33746	.05594	1.06086
Residual Sum of Squares		.27898	.05229	.72146
Std. Dev. of Estimate		.19963	.10227	.22701
R-squared		.17332	.06521	.31993
Adjusted R-squared		.05522	-.12175	.27135
Degrees of Freedom (df)		7	5	14
Number of Ind Vars (K)		2	2	2
F(K-1, df)		1.46758	.34879	6.58615
Prob. Value of F		.26503	.58048	.02240
Constant		.78102	.98136	1.03270
Standard error		.15633	.07799	.11037
Slope		-.04105	.01893	-.07421
Standard error		.03388	.03205	.02892
t-ratio		-1.21144	.59059	-2.56635
prob t		.26503	.58048	.02240
Correlation Coefficient		-.41631	.25536	-.56562

[1]See Section 4 for discussion of regression equations and units.

Table C-96. ANOVA for **check sight** with crews in MOPP4-R.

	Sum Sq	*DF*	*Mean Sq*
Crew	.66746	1	.39340
Error	.66746	14	.02810

Mean of Dependent Variable	.78978
Number of Observations	16
Total Sum of Squares	1.06086
Residual Sum of Squares	.39340
Std. Dev. of Estimate	.16763
R-squared	.62917
Adjusted R-squared	.60268
Degrees of Freedom (df)	14
Number of Ind Vars (K)	2
F(K-1, df)	23.75276
Prob. Value of F	.00025

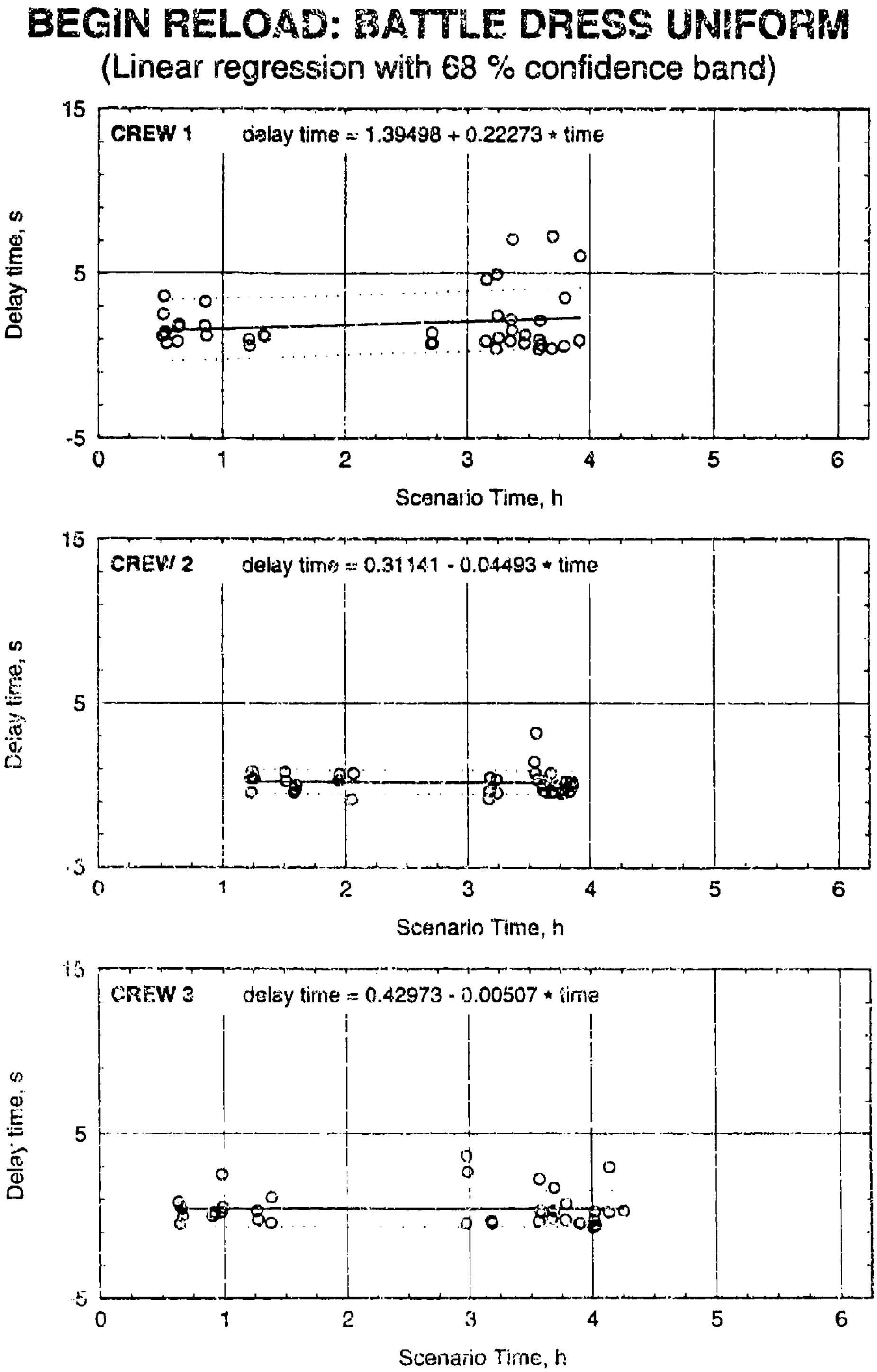


Figure C-97. Task times with regression lines for **begin reload** in BDU.

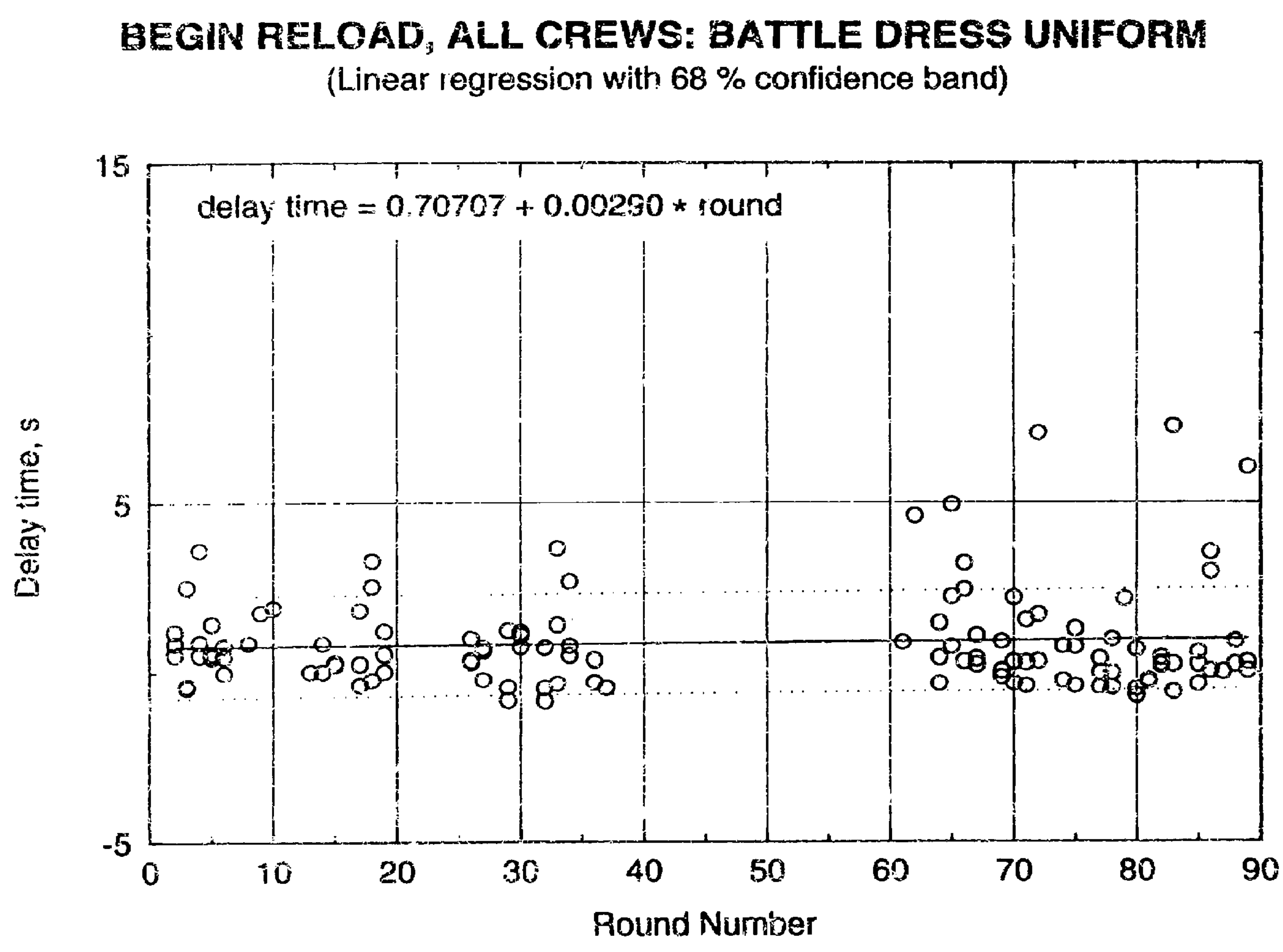


Figure C-98. Aggregate task time data with regression line for **begin reload** in BDU.

Table C-97. Statistical summary[1] for **begin reload** with crews in BDU.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	1.93625	.18125	.41641	.84824
Number of Observations	40	40	39	119
Total Sum of Squares	124.08950	19.17803	42.57849	258.26430
Residual Sum of Squares	120.79240	19.09668	42.57661	257.37090
Std. Dev. of Estimate	1.78290	.70890	1.07272	1.48316
R-squared	.02657	.00424	.00004	.00346
Adjusted R-squared	.00095	-.02196	-.02698	-.00506
Degrees of Freedom (df)	38	38	37	117
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	1.03723	.16188	.00163	.40613
Prob. Value of F	.31491	.68969	.96800	.52518
Constant	1.39498	.31141	.42973	.70707
Standard error	.60161	.34238	.37175	.25991
Slope	.22273	-.04493	-.00507	.00290
Standard error	.21870	.11166	.12546	.00456
t-ratio	1.01845	-.40234	-.04039	.63729
prob t	.31491	.68969	.96800	.52518
Correlation Coefficient	.16300	-.06513	-.00664	.05882

[1]See Section 4 for discussion of regression equations and units.

Table C-98. ANOVA for **begin reload** with crews in BDU.

	Sum Sq	*DF*	*Mean Sq*
Crew	72.41825	2	185.84610
Error	36.20913	116	1.60212

Mean of Dependent Variable	.84824
Number of Observations	119
Total Sum of Squares	258.26430
Residual Sum of Squares	185.84610
Std. Dev. of Estimate	1.26575
R-squared	.28040
Adjusted R-squared	.26800
Degrees of Freedom (df)	116
Number of Ind Vars (K)	3
F(K-1, df)	22.60074
Prob. Value of F	.00000

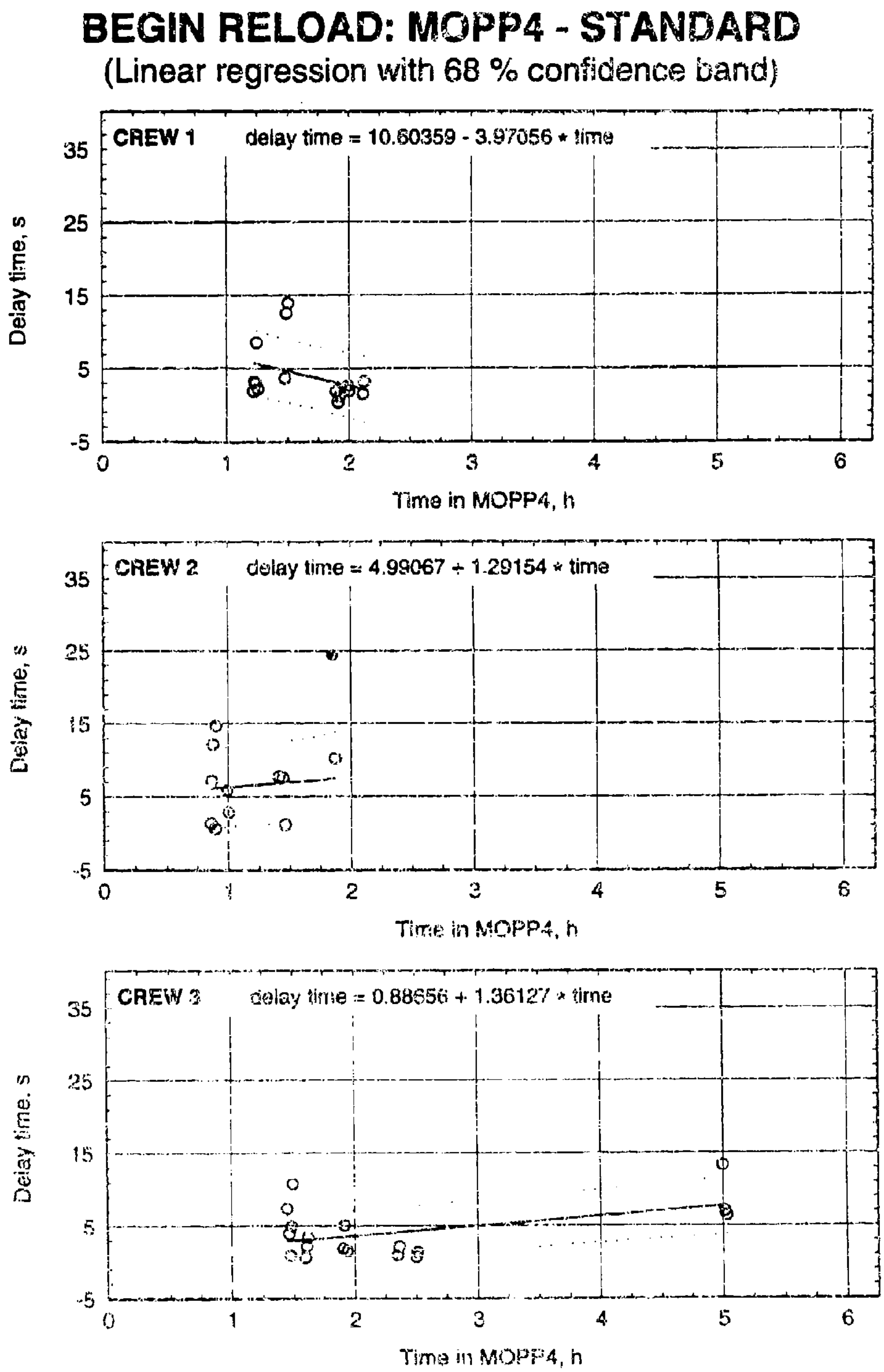


Figure C-99. Task times with regression lines for **begin reload** in MOPP4-S.

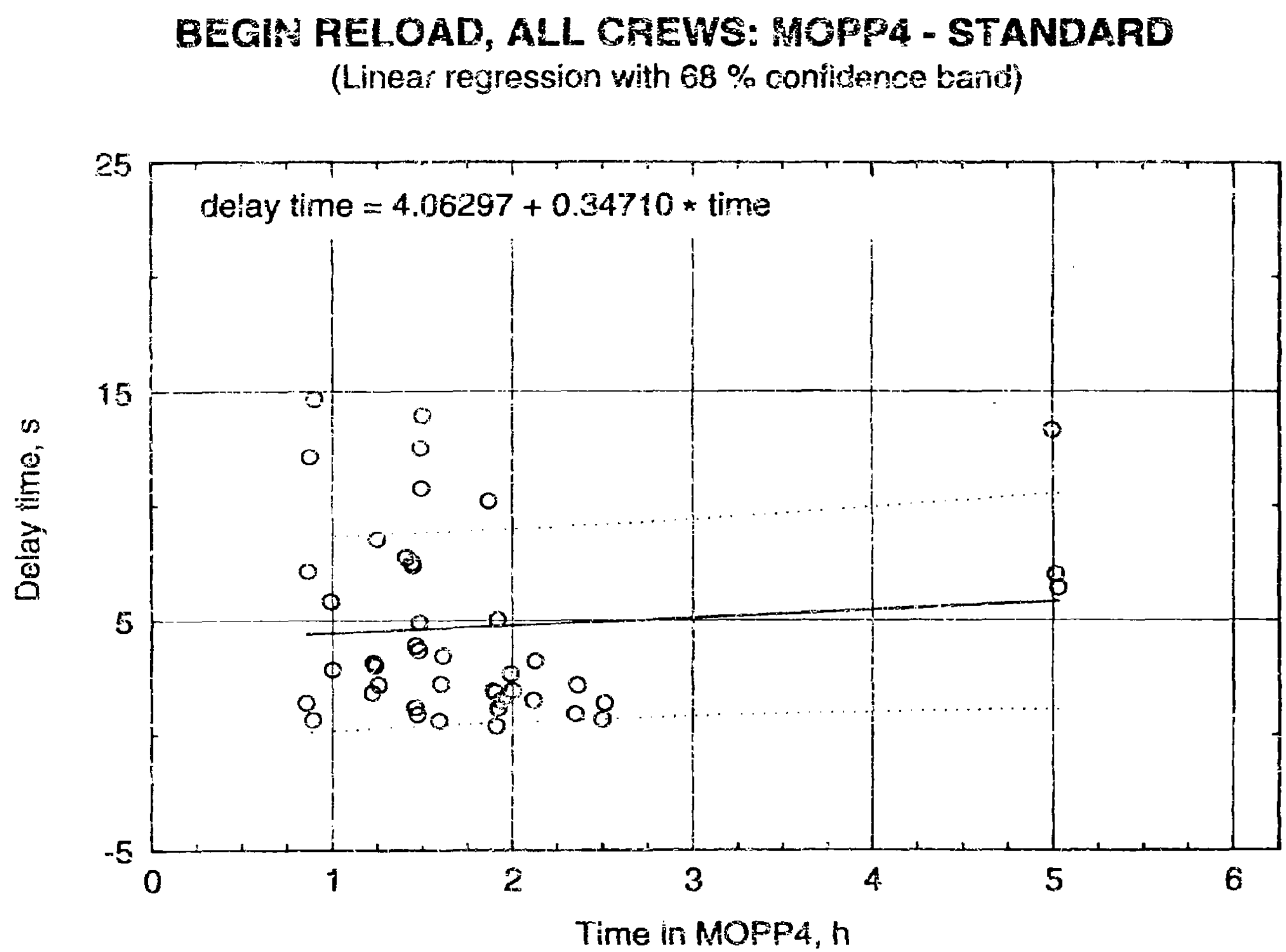


Figure C-100. Aggregate task time data with regression line for **begin reload** in MOPP4-S.

Table C-99. Statistical summary[1] for **begin reload** with crews in MOPP4-S.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	4.08733	6.46636	4.11389	4.69295
Number of Observations	15	11	18	44
Total Sum of Squares	240.42860	217.96380	227.90820	732.43280
Residual Sum of Squares	211.85450	215.98550	177.02070	727.43930
Std. Dev. of Estimate	4.03689	4.89882	3.32623	4.16173
R-squared	.11885	.00908	.22328	.00682
Adjusted R-squared	.05107	-.10103	.17474	-.01683
Degrees of Freedom (df)	13	9	16	42
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	1.75339	.08243	4.59946	.28831
Prob. Value of F	.20826	.78053	.04768	.59414
Constant	10.60359	4.99067	.88656	4.06297
Standard error	5.03024	5.34779	1.69682	1.33050
Slope	-3.97056	1.29154	1.36127	.34710
Standard error	2.99856	4.49836	.63473	.64643
t-ratio	-1.32416	.28711	2.14463	.53694
prob t	.20826	.78053	.04768	.59414
Correlation Coefficient	-.34474	.09527	.47253	.08257

[1]See Section 4 for discussion of regression equations and units.

Table C-100. ANOVA for **begin reload** with crews in MOPP4-S.

	Sum Sq	*DF*	*Mean Sq*
Crew	46.13214	2	686.30070
Error	23.06607	41	16.73904

Mean of Dependent Variable	4.69295
Number of Observations	44
Total Sum of Squares	732.43280
Residual Sum of Squares	686.30070
Std. Dev. of Estimate	4.09134
R-squared	.06298
Adjusted R-squared	.01728
Degrees of Freedom (df)	41
Number of Ind Vars (K)	3
F(K-1, df)	1.37798
Prob. Value of F	.26352

BEGIN RELOAD: MOPP4 - ROTATING
(Linear regression with 68 % confidence band)

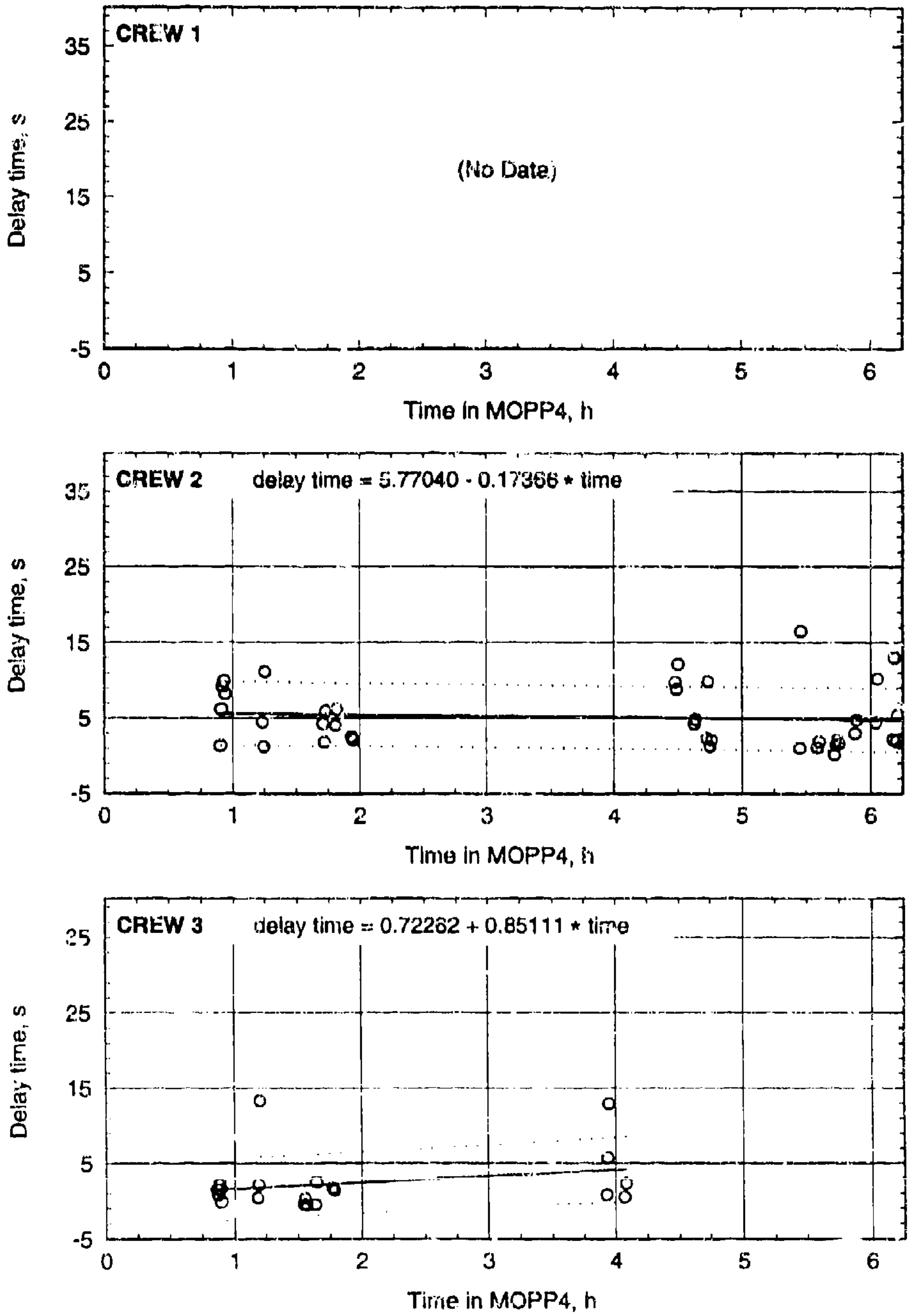


Figure C-101. Task times with regression lines for **begin reload** in MOPP4-R.

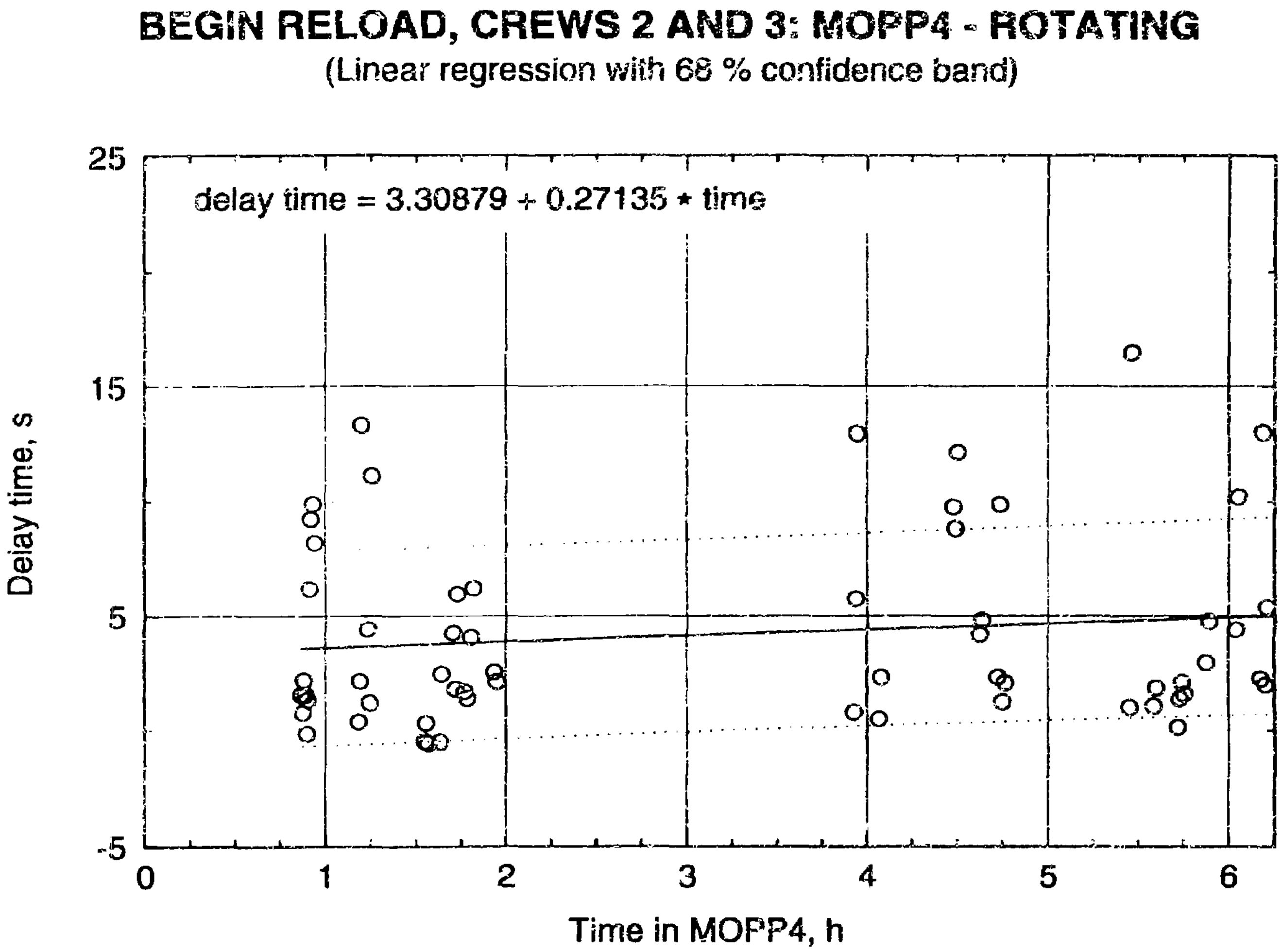


Figure C-102. Aggregate task time data with regression line for **begin reload** in MOPP4-R.

Table C-101. Statistical summary[1] for **begin reload** with crews in MOPP4-R.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	No Data	5.09125	2.40150	4.19467
Number of Observations		40	20	60
Total Sum of Squares		631.18020	293.68540	1021.32900
Residual Sum of Squares		626.25200	272.69470	1003.47500
Std. Dev. of Estimate		4.05960	3.89226	4.15948
R-squared		.00781	.07147	.01748
Adjusted R-squared		-.01830	.01989	.00054
Degrees of Freedom (df)		38	18	58
Number of Ind Vars (K)		2	2	2
F(K-1, df)		.29903	1.38555	1.03192
Prob. Value of F		.58769	.25449	.31393
Constant		5.77040	.72262	3.30879
Standard error		1.39802	1.67086	1.02414
Slope		-.17366	.85111	.27135
Standard error		.31757	.72306	.26712
t-ratio		-.54684	1.17710	1.01583
prob t		.58769	.25449	.31393
Correlation Coefficient		-.08836	.26735	.13221

[1]See Section 4 for discussion of regression equations and units.

Table C-102. ANOVA for **begin reload** with crews in MOPP4-R.

	Sum Sq	*DF*	*Mean Sq*
Crew	96.46339	1	924.86560
Error	95.46339	58	15.94596

Mean of Dependent Variable	4.19467
Number of Observations	60
Total Sum of Squares	1021.32900
Residual Sum of Squares	924.86560
Std. Dev. of Estimate	3.99324
R-squared	.09445
Adjusted R-squared	.07884
Degrees of Freedom (df)	58
Number of Ind Vars (K)	2
F(K-1, df)	6.04939
Prob. Value of F	.01691

RELOAD POWDER: BATTLE DRESS UNIFORM

(Linear regression with 68 % confidence band)

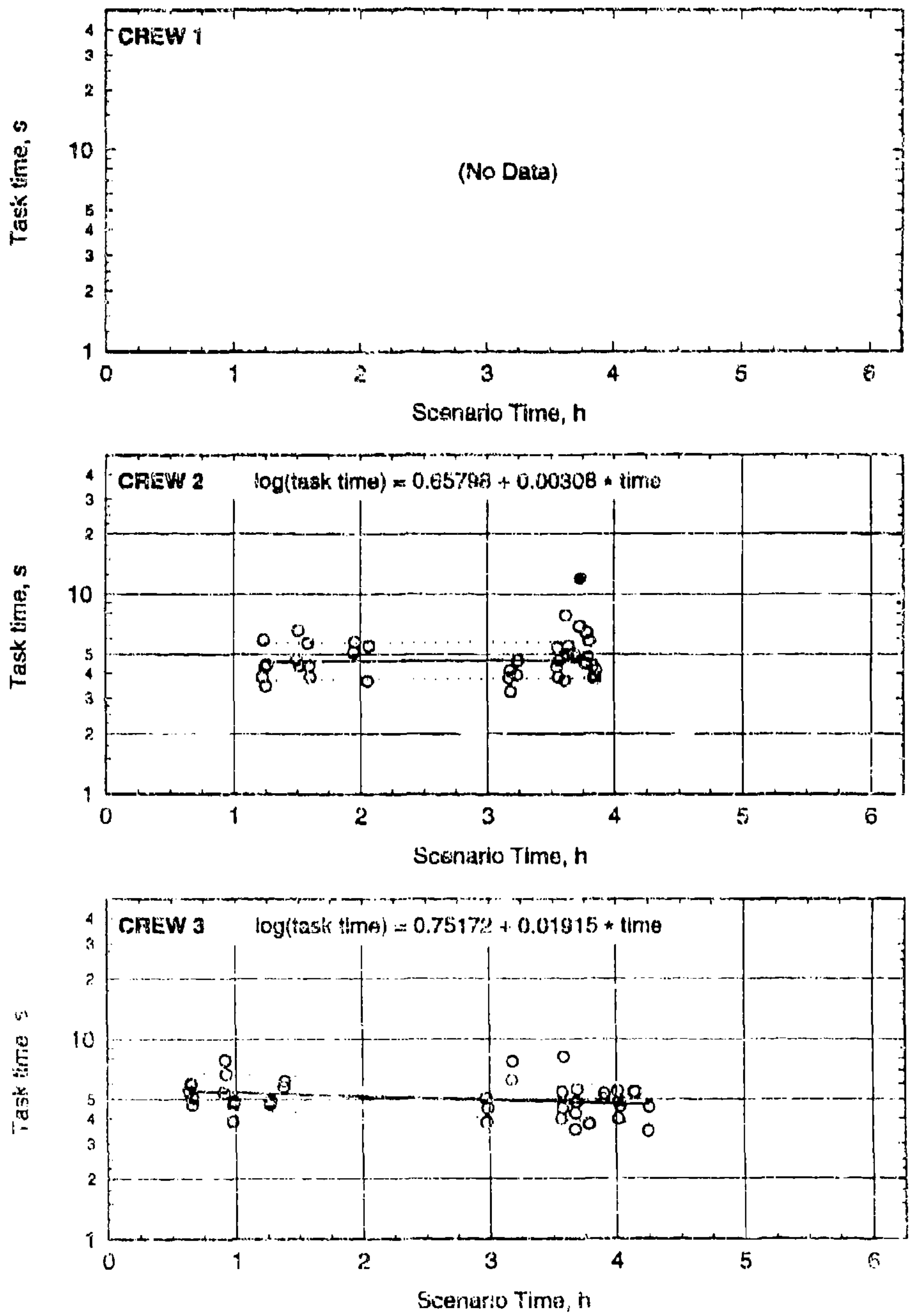


Figure C-103. Task times with regression lines for **reload powder** in BDU.

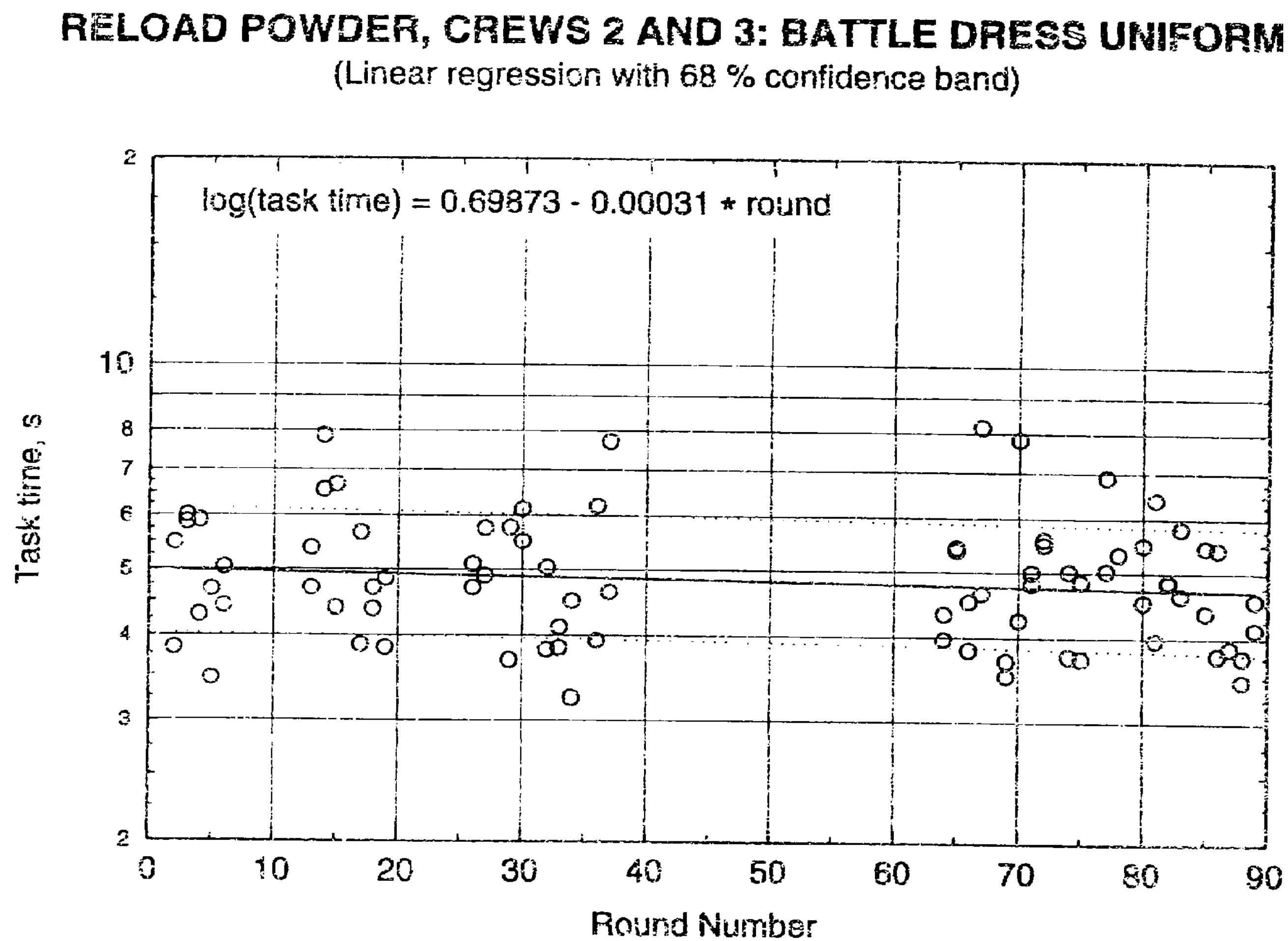


Figure C-104. Aggregate task time data with regression line for **reload powder** in BDU.

Table C-103. Statistical summary[1] for **reload powder** with crews in BDU.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	No Data	.66674	.70061	.68367
Number of Observations		40	40	80
Total Sum of Squares		.30567	.31980	.64842
Residual Sum of Squares		.30528	.29206	.64144
Std. Dev. of Estimate		.08963	.08767	.09068
R-squared		.00129	.08675	.01077
Adjusted R-squared		-.02500	.06272	-.00191
Degrees of Freedom (df)		38	38	78
Number of Ind Vars (K)		2	2	2
F(K-1, df)		.04892	3.60980	.84923
Prob. Value of F		.82614	.06505	.35961
Constant		.65798	.75172	.69873
Standard error		.04203	.03026	.01923
Slope		.00308	-.01915	-.00031
Standard error		.01392	.01008	.00034
t-ratio		.22117	-1.89995	-.92154
prob t		.82614	.06505	.35961
Correlation Coefficient		.03586	-.29454	-.10378

[1]See Section 4 for discussion of regression equations and units.

Table C-104. ANOVA for **reload powder** with crews in BDU.

	Sum Sq	*DF*	*Mean Sq*
Crew	.02295	1	.62548
Error	.02295	78	.00802

Mean of Dependent Variable	.68367
Number of Observations	80
Total Sum of Squares	.64842
Residual Sum of Squares	.62548
Std. Dev. of Estimate	.08955
R-squared	.03539
Adjusted R-squared	.02302
Degrees of Freedom (df)	78
Number of Ind Vars (K)	2
F(K-1, df)	2.86148
Prob. Value of F	.09472

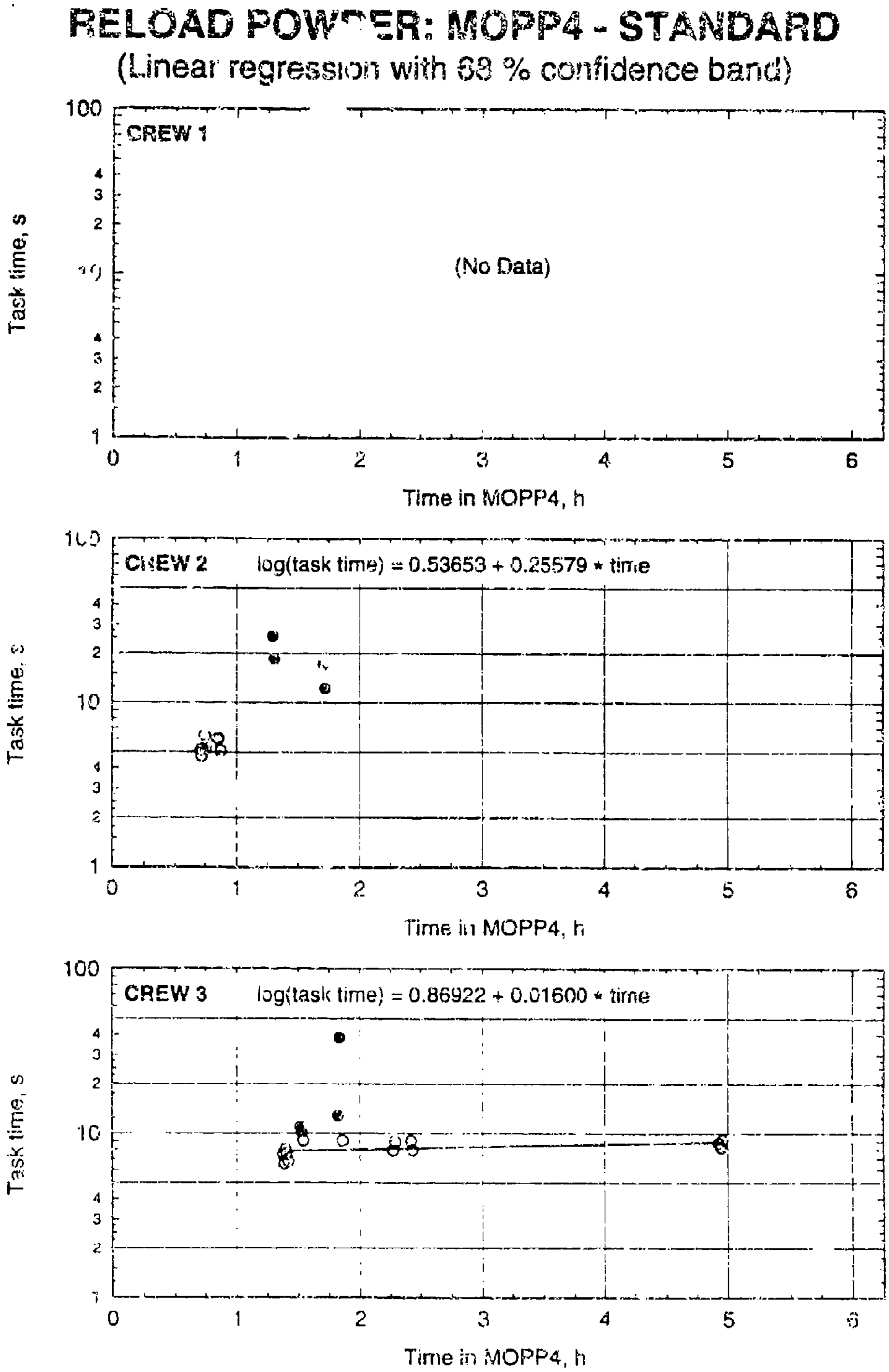


Figure C-105. Task times with regression lines for **reload powder** in MOPP4-S.

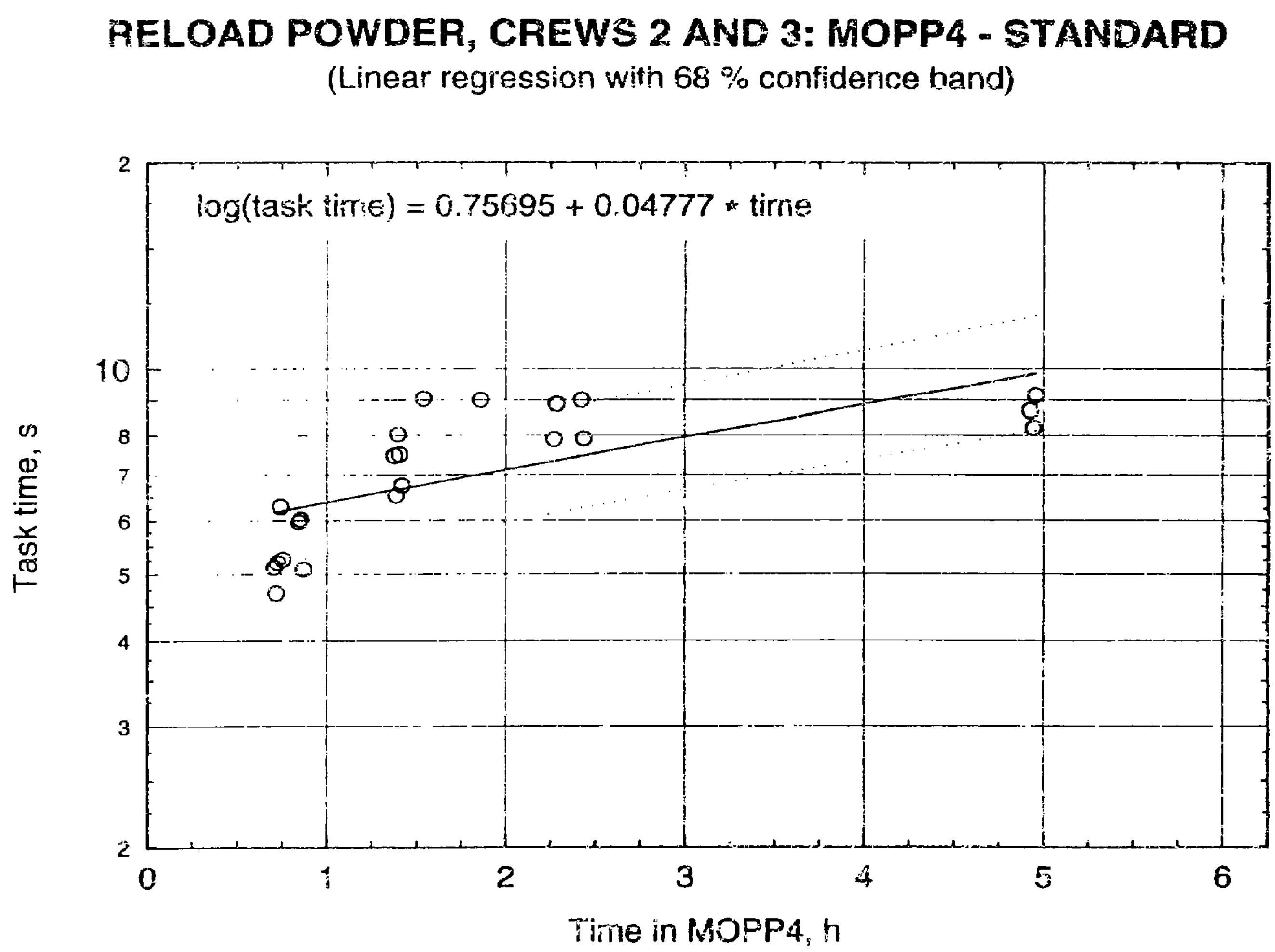


Figure C-106. Aggregate task time data with regression line for **reload powder** in MOPP4-S.

Table C-105. Statistical summary[1] for **reload powder** with crews in MOPP4-S.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	No Data	.73499	.90877	.84558
Number of Observations		8	14	22
Total Sum of Squares		.01385	.02971	.19730
Residual Sum of Squares		.01178	.02321	.10580
Std. Dev. of Estimate		.04431	.04398	.07273
R-squared		.14912	.21891	.46375
Adjusted R-squared		.00730	.15382	.43693
Degrees of Freedom (df)		6	12	20
Number of Ind Vars (K)		2	2	2
F(K-1, df)		1.05151	3.36321	17.29585
Prob. Value of F		.34471	.09157	.00049
Constant		.53653	.86922	.75695
Standard error		.19417	.02456	.02636
Slope		.25579	.01600	.04777
Standard error		.24944	.00872	.01149
t-ratio		1.02543	1.83391	4.15883
prob t		.34471	.09157	.00049
Correlation Coefficient		.38616	.46788	.68099

[1]See Section 4 for discussion of regression equations and units.

Table C-106. ANOVA for **reload powder** with crews in MOPP4-S.

	Sum Sq	*DF*	*Mean Sq*
Crew	.15374	1	.04356
Error	.15374	20	.00218

Mean of Dependent Variable	.84558
Number of Observations	22
Total Sum of Squares	.19730
Residual Sum of Squares	.04356
Std. Dev. of Estimate	.04667
R-squared	.77923
Adjusted R-squared	.76819
Degrees of Freedom (df)	20
Number of Ind Vars (K)	2
F(K-1, df)	70.59100
Prob. Value of F	.00000

RELOAD POWDER: MOPP4 - ROTATING

(Linear regression with 68 % confidence band)

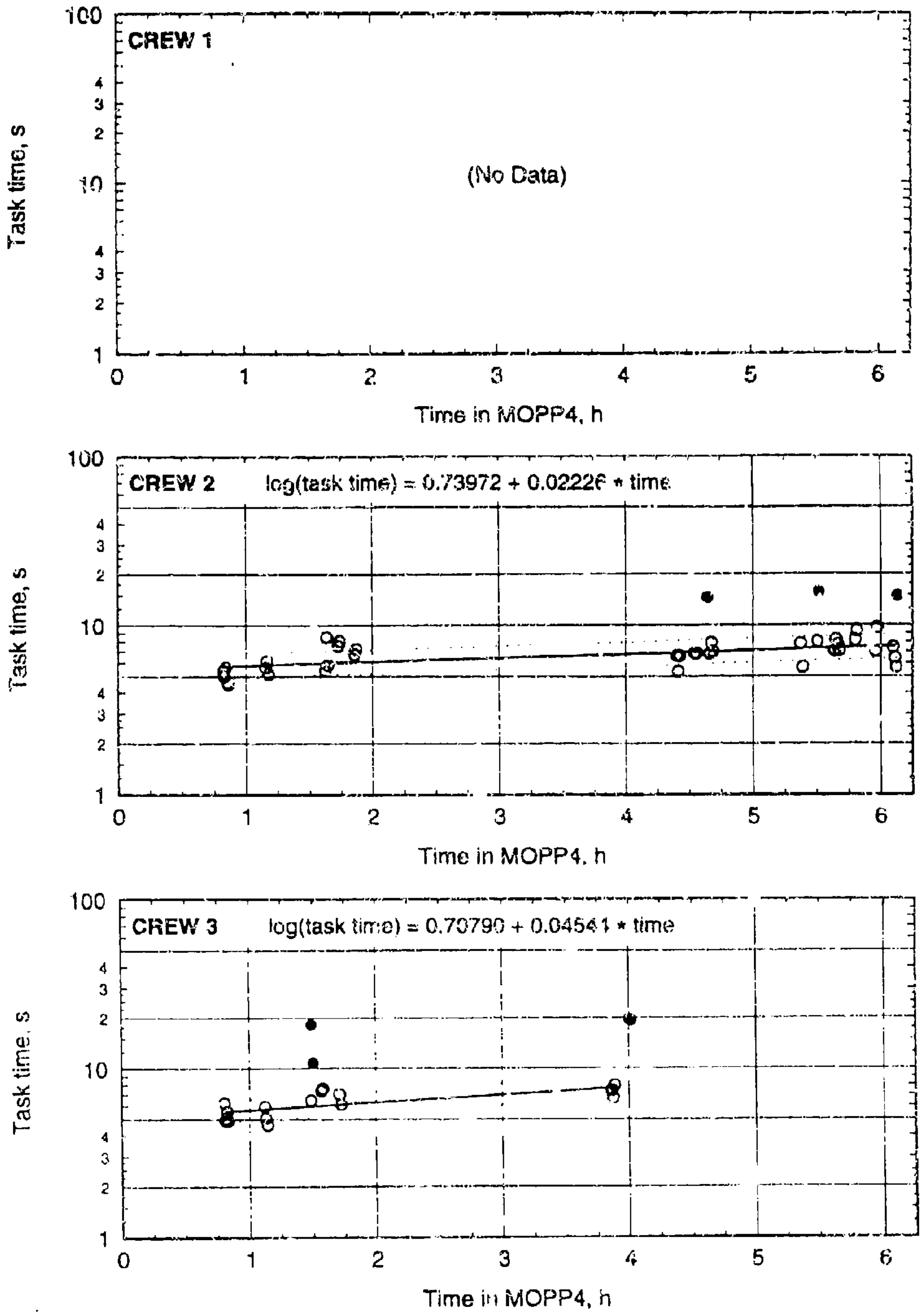


Figure C-107. Task times with regression lines for **reload powder** in MOPP4-R.

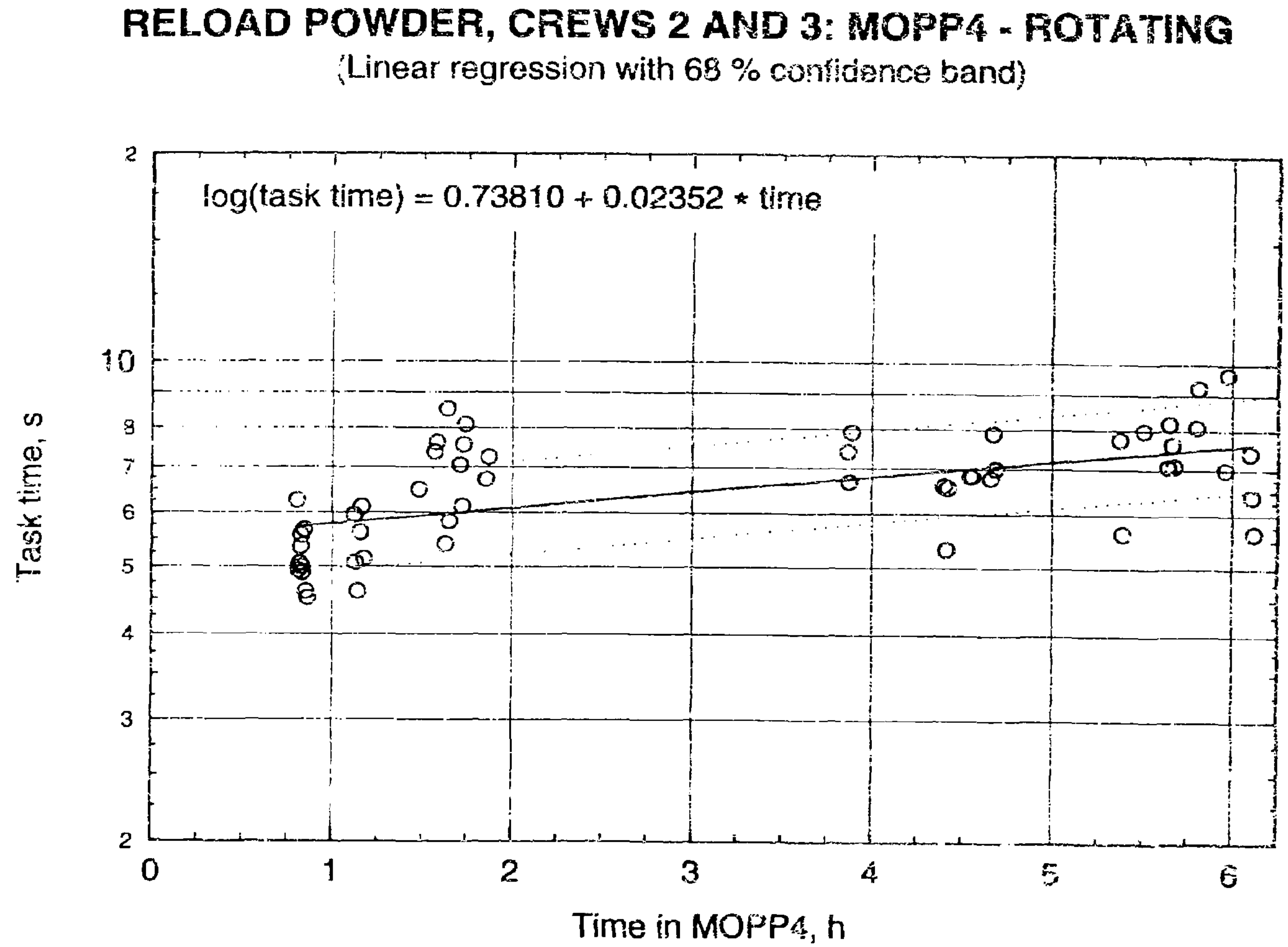


Figure C-108. Aggregate task time data with regression line for reload powder in MOPP4-R.

Table C-107. Statistical summary[1] for **reload powder** with crews in MOPP4-R.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	No Data	.82211	.78507	.81093
Number of Observations		37	16	53
Total Sum of Squares		.24394	.08917	.34843
Residual Sum of Squares		.16764	.04970	.22790
Std. Dev. of Estimate		.06921	.05958	.06685
R-squared		.31276	.44269	.34593
Adjusted R-squared		.29313	.40289	.33310
Degrees of Freedom (df)		35	14	51
Number of Ind Vars (K)		2	2	2
F(K-1, df)		15.92867	11.12086	26.97329
Prob. Value of F		.00032	.00491	.00000
Constant		.73972	.70790	.73810
Standard error		.02357	.02752	.01676
Slope		.02226	.04544	.02352
Standard error		.00558	.01363	.00453
t-ratio		3.99107	3.33479	5.19358
prob t		.00032	.00491	00000
Correlation Coefficient		.55925	.66535	.58816

[1]See Section 4 for discussion of regression equations and units.

Table C-108. ANOVA for **reload powder** with crews in MOPP4-R.

	Sum Sq	*DF*	*Mean Sq*
Crew	.01532	1	.33311
Error	.01532	51	.00653

Mean of Dependent Variable	.81093
Number of Observations	53
Total Sum of Squares	.34843
Residual Sum of Squares	.33311
Std. Dev. of Estimate	.08082
R-squared	.04398
Adjusted R-squared	.02524
Degrees of Freedom (df)	51
Number of Ind Vars (K)	2
F(K-1, df)	2.34629
Prob. Value of F	.13176

RELOAD PROJO AND PWDR: BDU

(Linear regression with 68 % confidence band)

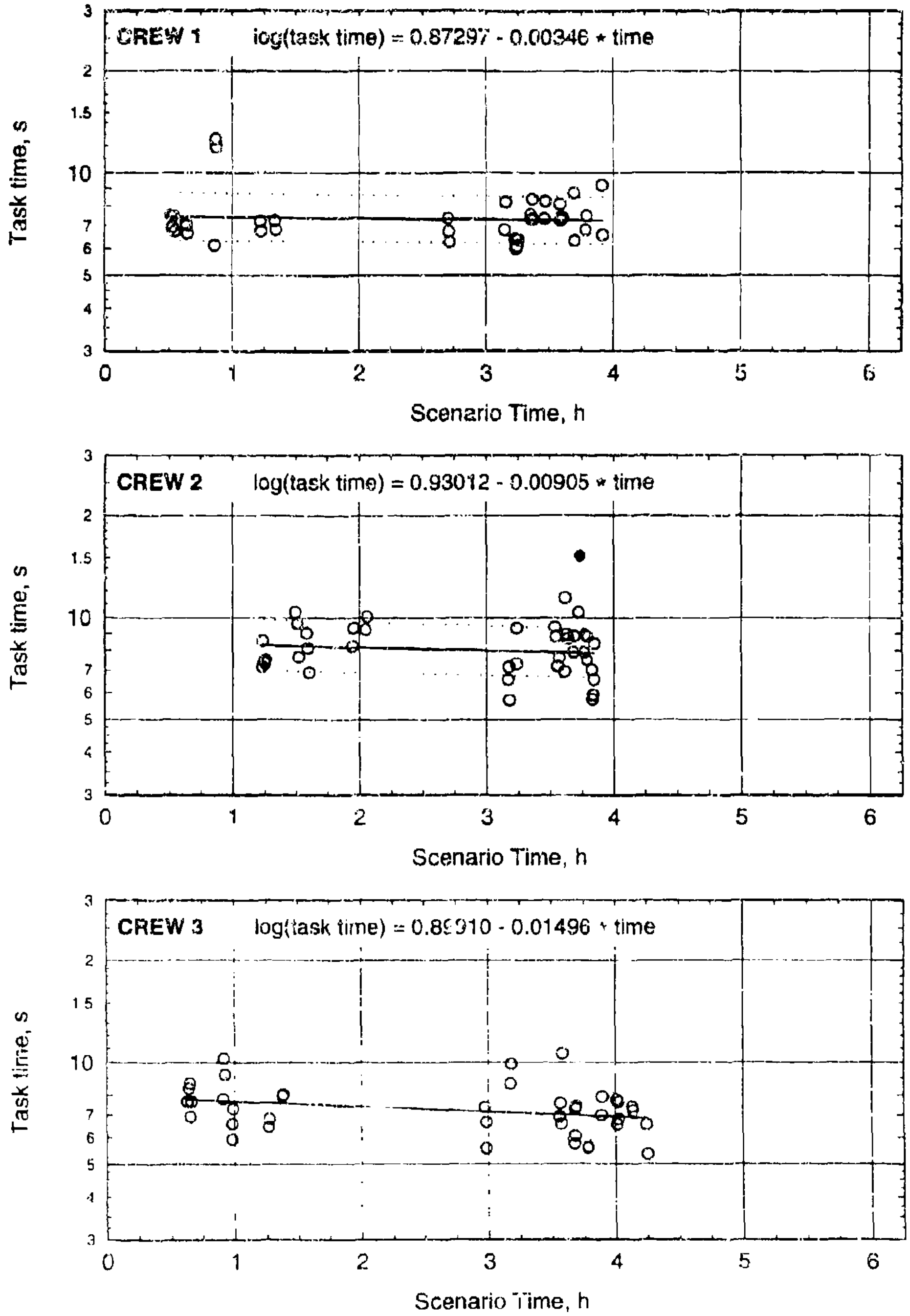


Figure C-109. Task times with regression lines for **reload projo and pwdr** in BDU.

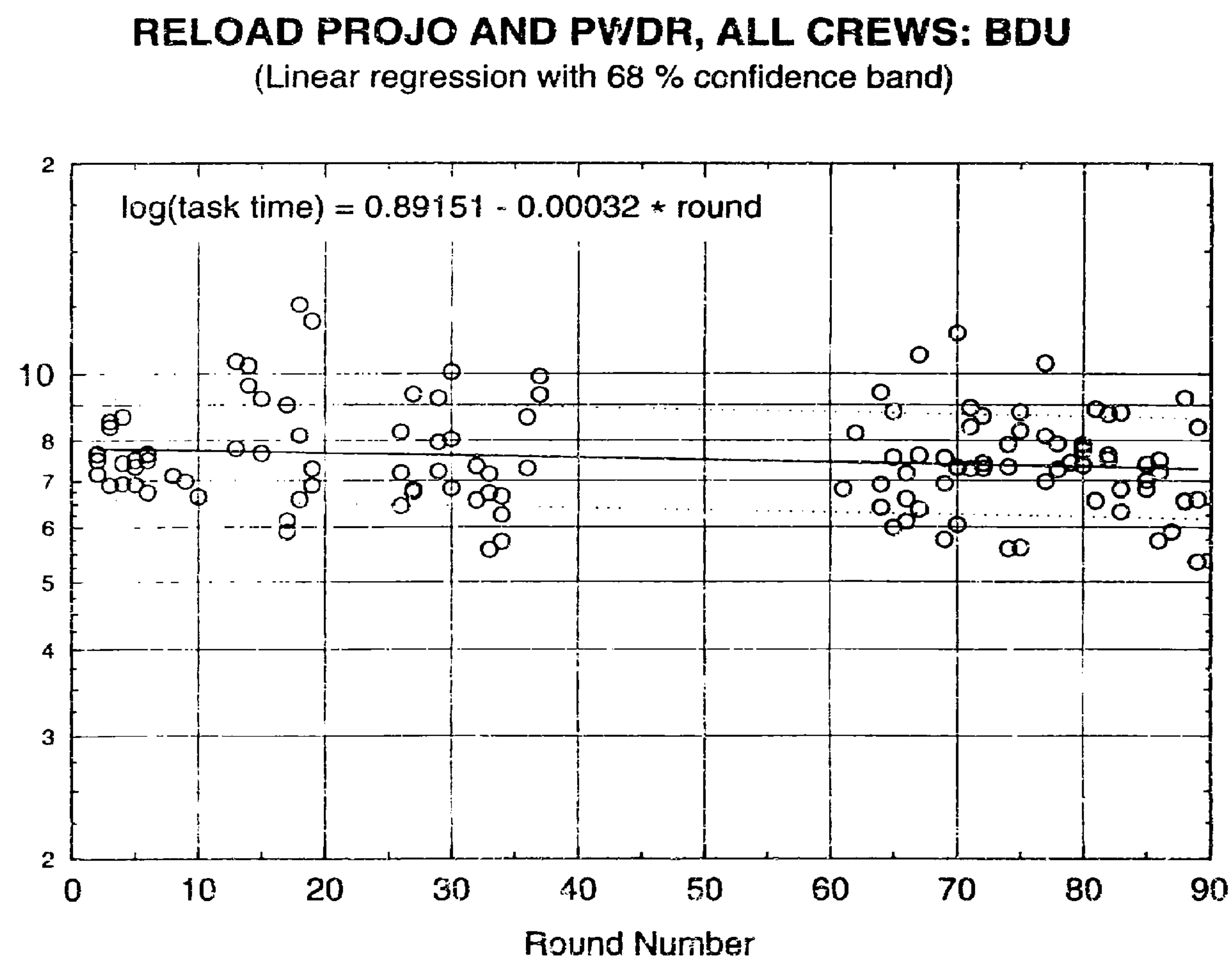


Figure C-110. Aggregate task time data with regression line for reload projo and pwdr in BDU.

Table C-109. Statistical summary[1] for **reload projo and pwdr** with crews in BDU.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	.86456	.90441	.85919	.87606
Number of Observations	40	40	40	120
Total Sum of Squares	.17413	.19653	.19750	.61698
Residual Sum of Squares	.17334	.19314	.18057	.60598
Std. Dev. of Estimate	.06754	.07129	.06893	.07166
R-squared	.00457	.01727	.08568	.01782
Adjusted R-squared	-.02163	-.00859	.06162	.00950
Degrees of Freedom (df)	38	38	38	118
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	.17442	.66797	3.56104	2.14135
Prob. Value of F	.67857	.41885	.06681	.14603
Constant	.87297	.93012	.89910	.89151
Standard error	.02279	.03342	.02379	.01242
Slope	-.00346	-.00905	-.01496	-.00032
Standard error	.00828	.01107	.00793	.00022
t-ratio	-.41763	-.81730	-1.88707	-1.46334
prob t	.67857	.41885	.06681	.14603
Correlation Coefficient	-.06759	-.13143	-.29272	-.13351

[1]See Section 4 for discussion of regression equations and units.

Table C-110. ANOVA for **reload projo and pwdr** with crews in BDU.

	Sum Sq	*DF*	*Mean Sq*
Crew	.04882	2	.56816
Error	.02441	117	.00486

Mean of Dependent Variable	.87606
Number of Observations	120
Total Sum of Squares	.61698
Residual Sum of Squares	.56816
Std. Dev. of Estimate	.06969
R-squared	.07913
Adjusted R-squared	.06339
Degrees of Freedom (df)	117
Number of Ind Vars (K)	3
F(K-1, df)	5.02698
Prob. Value of F	.00805

RELOAD PROJO AND PWDR: MOPP4 - STANDARD
(Linear regression with 68 % confidence band)

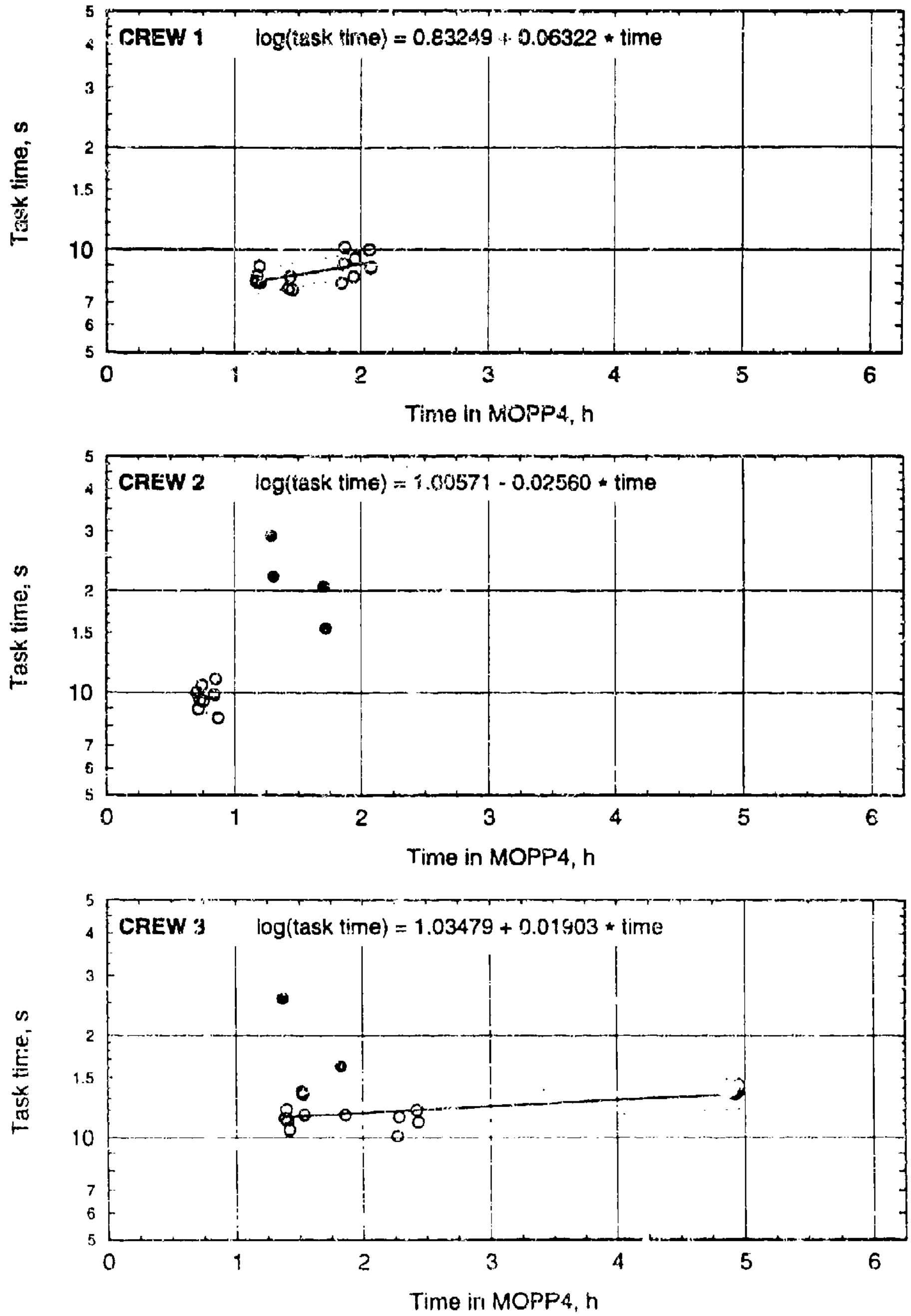


Figure C-111. Task times with regression lines for **reload projo and pwdr** in MOPP4-S.

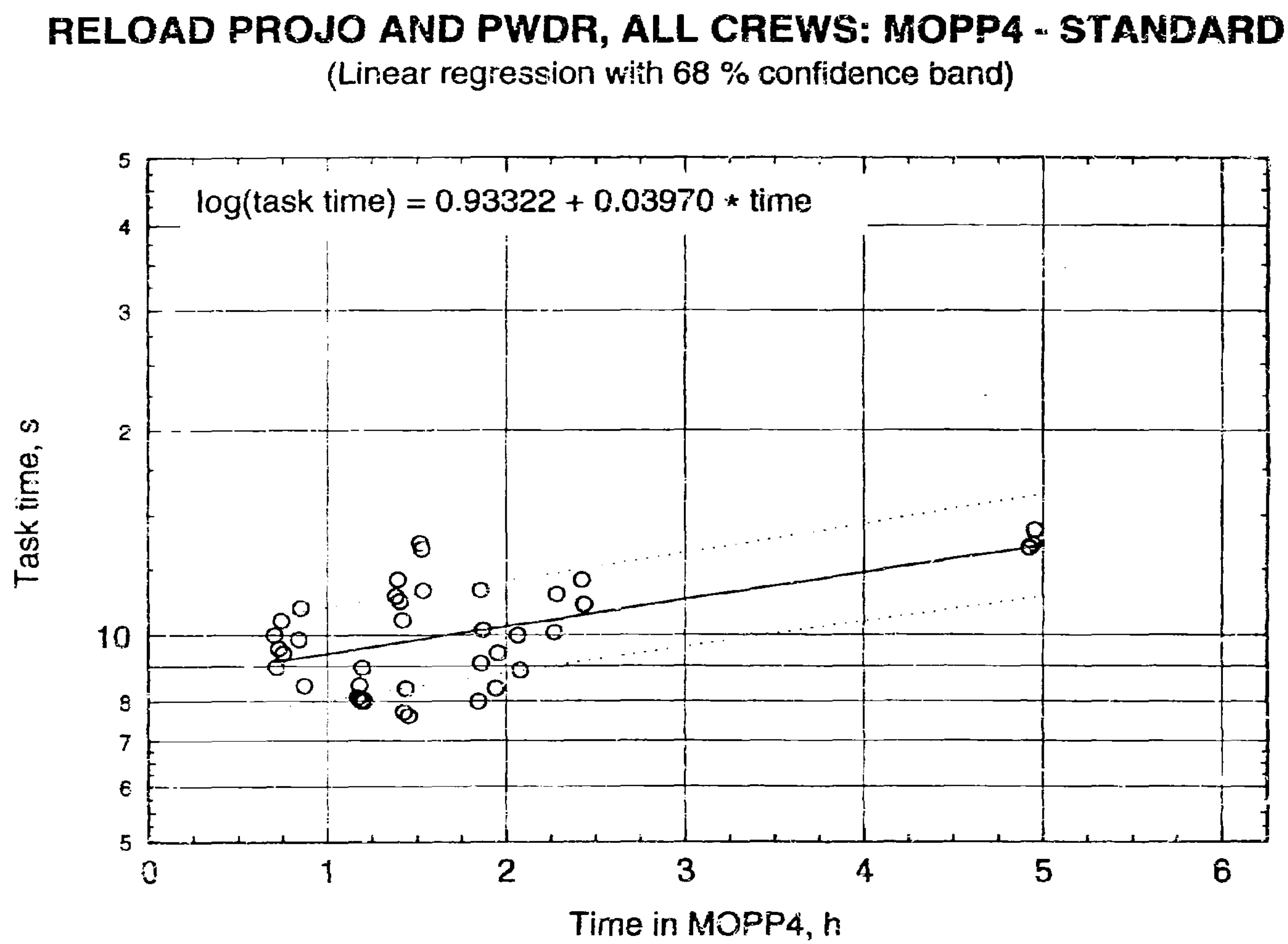


Figure C-112. Aggregate task time data with regression line for **reload projo and pwdr** in MOPP4-S.

Table C-111. Statistical summary[1] for **reload projo and pwdr** with crews in MOPP4-S.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	.93309	.98588	1.08078	1.00250
Number of Observations	15	8	15	38
Total Sum of Squares	.02105	.00935	.02849	.22528
Residual Sum of Squares	.01382	.00933	.01909	.15834
Std. Dev. of Estimate	.03260	.03944	.03832	.06632
R-squared	.34348	.00221	.33000	.29714
Adjusted R-squared	.29298	-.16408	.27846	.27761
Degrees of Freedom (df)	13	6	13	36
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	6.80146	.01332	6.40295	15.21901
Prob. Value of F	.02168	.91189	.02511	.00040
Constant	.83249	1.00571	1.03479	.93322
Standard error	.03948	.17241	.02069	.02077
Slope	.06322	-.02560	.01903	.03970
Standard error	.02424	.22182	.00752	.01018
t-ratio	2.60796	-.11540	2.53041	3.90115
prob t	.02168	.91189	.02511	.00040
Correlation Coefficient	.58607	-.04706	.57446	.54510

[1]See Section 4 for discussion of regression equations and units.

Table C-112. ANOVA for **reload projo and pwdr** with crews in MOPP4-S.

	Sum Sq	*DF*	*Mean Sq*
Crew	.16640	2	.05889
Error	.08320	35	.00168

Mean of Dependent Variable	1.00250
Number of Observations	38
Total Sum of Squares	.22528
Residual Sum of Squares	.05889
Std. Dev. of Estimate	.04102
R-squared	.73860
Adjusted R-squared	.72367
Degrees of Freedom (df)	35
Number of Ind Vars (K)	3
F(K-1, df)	49.44798
Prob. Value of F	.00000

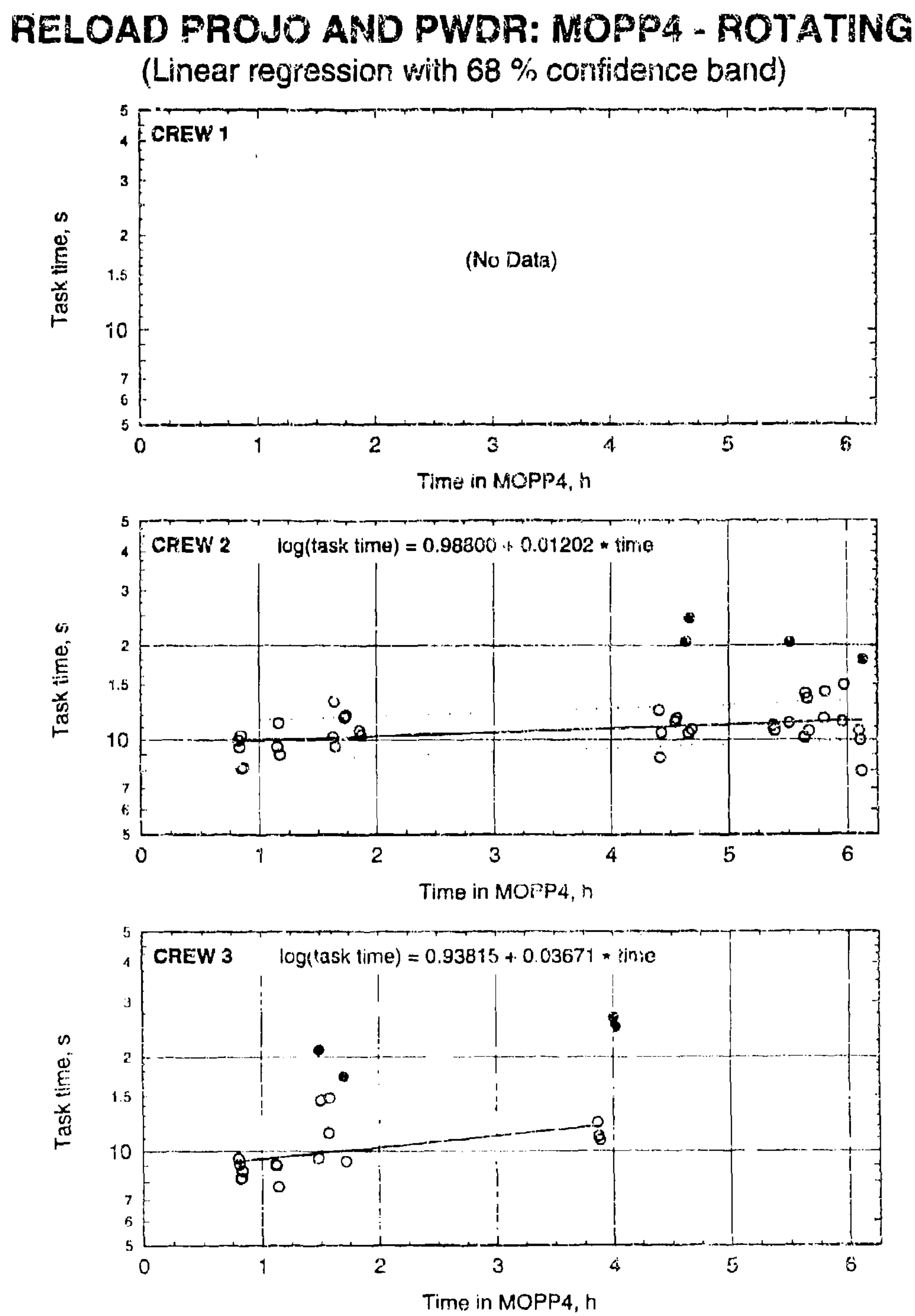


Figure C-113. Task times with regression lines for **reload projo and pwdr** in MOPP4-R.

RELOAD PROJO AND PWDR, CREWS 2 AND 3: MOPP4 - ROTATING

(Linear regression with 68 % confidence band)

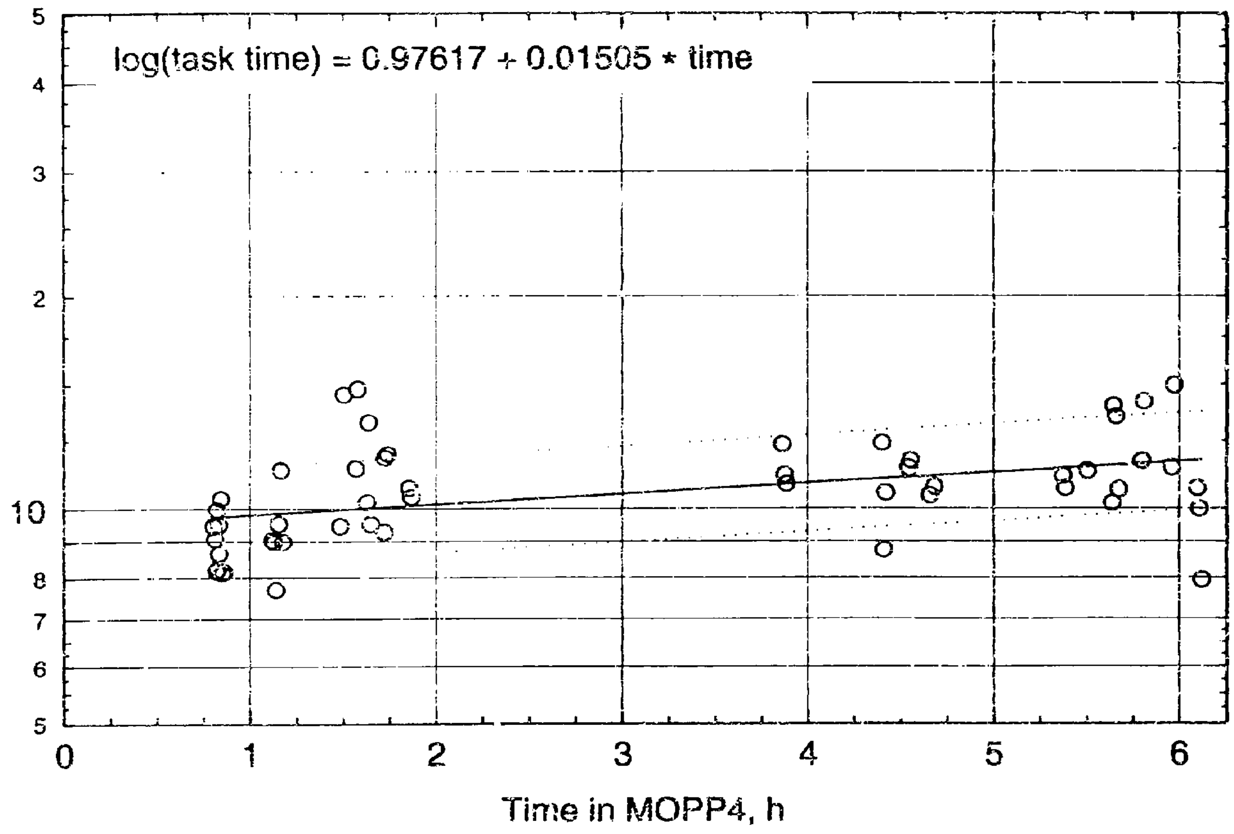


Figure C-114. Aggregate task time data with regression line for reload projo and pwdr in MOPP4-R.

Table C-113. Statistical summary[1] for **reload projo and pwdr** with crews in MOPP4-R.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	No Data	1.03216	.99998	1.02226
Number of Observations		36	16	52
Total Sum of Squares		.152[illegible]0	.11020	.27397
Residual Sum of Squares		.13018	.08439	.22502
Std. Dev. of Estimate		.06188	.07764	.06709
R-squared		.14520	.23419	.17865
Adjusted R-squared		.12006	.17949	.16222
Degrees of Freedom (df)		34	14	50
Number of Ind Vars (K)		2	2	2
F(K-1, df)		5.77522	4.28141	10.87509
Prob. Value of F		.02186	.05752	.00180
Constant		.98800	.93815	.97617
Standard error		.02107	.03564	.01679
Slope		.01202	.03671	.01505
Standard error		.00500	.01774	.00457
t-ratio		2.40317	2.06916	3.29774
prob t		.02186	.05752	.00180
Correlation Coefficient		.38105	.48394	.42267

[1]See Section 4 for discussion of regression equations and units.

Table C-114. ANOVA for **reload projo and pwdr** with crews in MOPP4-R.

	Sum Sq	*DF*	*Mean Sq*
Crew	.01146	1	.26250
Error	.01146	50	.00525

Mean of Dependent Variable	1.02226
Number of Observations	52
Total Sum of Squares	.27397
Residual Sum of Squares	.26250
Std. Dev. of Estimate	.07246
R-squared	.04185
Adjusted R-squared	.02268
Degrees of Freedom (df)	50
Number of Ind Vars (K)	2
F(K-1, df)	2.18370
Prob. Value of F	.14575

LAST OPEN BREECH: BATTLE DRESS UNIFORM
(Linear regression with 68 % confidence band)

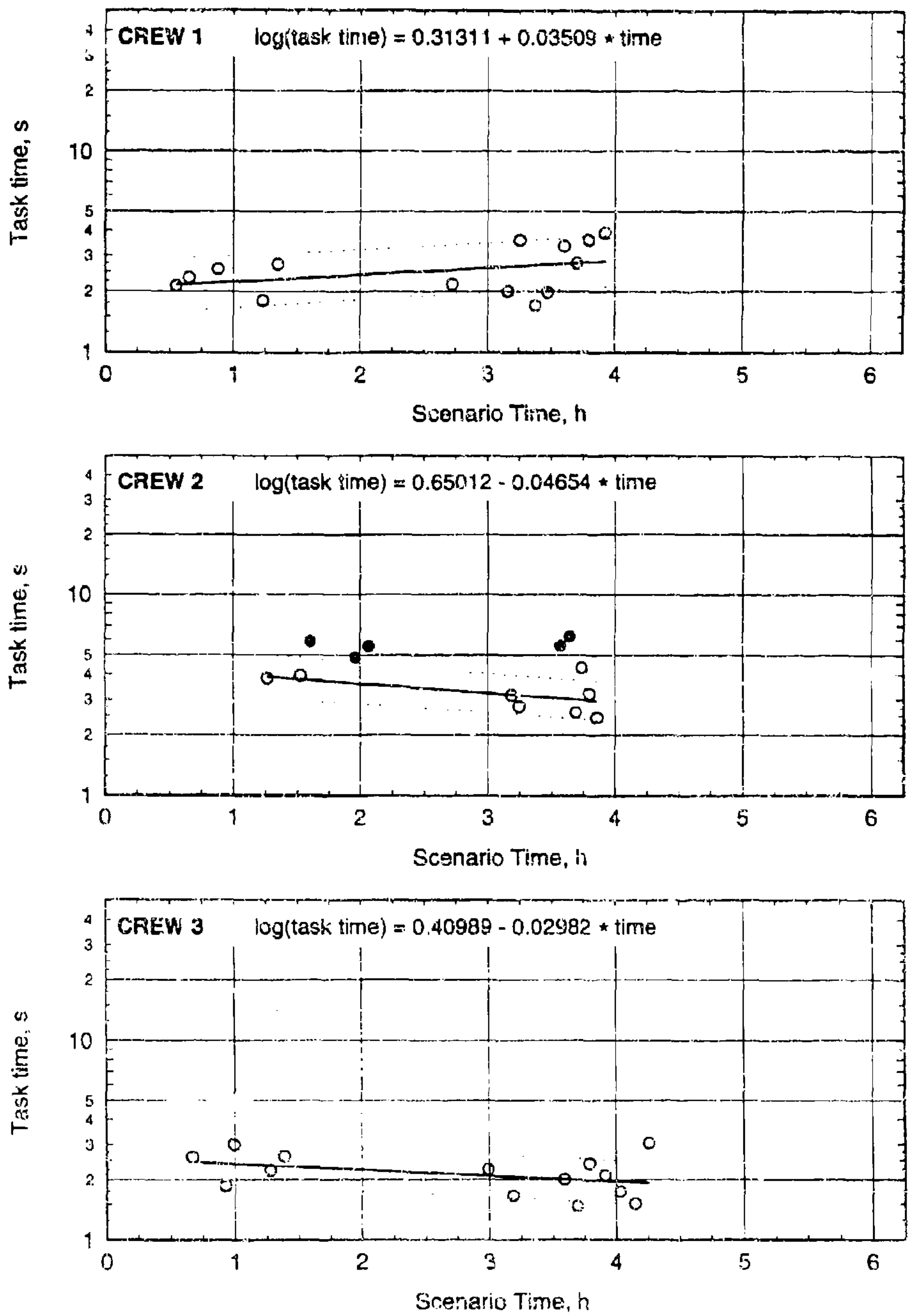


Figure C-115. Task times with regression lines for **last open breech** in BDU.

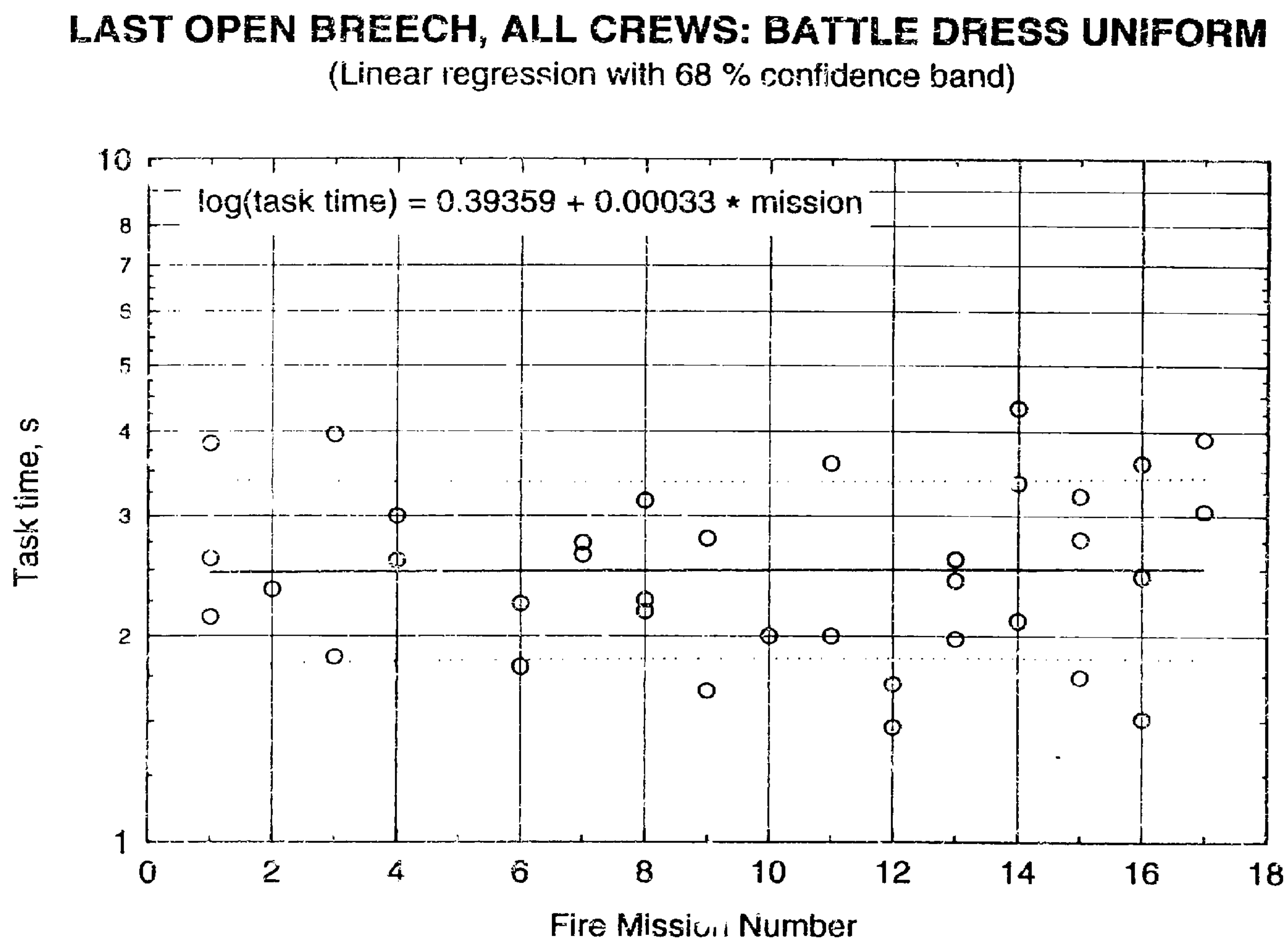


Figure C-116. Aggregate task time data with regression line for **last open breech** in BDU.

Table C-115. Statistical summary[1] for **last open breech** with crews in BDU.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	.40254	.50868	.32718	.39682
Number of Observations	14	8	14	36
Total Sum of Squares	.18381	.05805	.13819	.54851
Residual Sum of Squares	.15685	.04145	.11608	.54841
Std. Dev. of Estimate	.11433	.08312	.09835	.12700
R-squared	.14666	.28595	.16000	.00018
Adjusted R-squared	.07555	.16694	.09000	-.02922
Degrees of Freedom (df)	12	6	12	34
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	2.06238	2.40275	2.28575	.00617
Prob. Value of F	.17653	.17210	.15645	.93784
Constant	.31311	.65012	.40989	.39359
Standard error	.06937	.09586	.06069	.04629
Slope	.03509	-.04654	-.02982	.00033
Standard error	.02444	.03003	.01973	.00422
t-ratio	1.43610	-1.55008	-1.51187	.07856
prob t	.17653	.17210	.15645	.93784
Correlation Coefficient	.38296	-.53474	-.40000	.01347

[1]See Section 4 for discussion of regression equations and units.

Table C-116. ANOVA for **last open breech** with crews in BDU.

	Sum Sq	*DF*	*Mean Sq*
Crew	.16846	2	.38005
Error	.08423	33	.01152

Mean of Dependent Variable	.39682
Number of Observations	36
Total Sum of Squares	.54851
Residual Sum of Squares	.38005
Std. Dev. of Estimate	.10732
R-squared	.30713
Adjusted R-squared	.26513
Degrees of Freedom (df)	33
Number of Ind Vars (K)	3
F(K-1, df)	7.31384
Prob. Value of F	00235

LAST OPEN BREECH: MOPP4 - STANDARD

(Linear regression with 68 % confidence band)

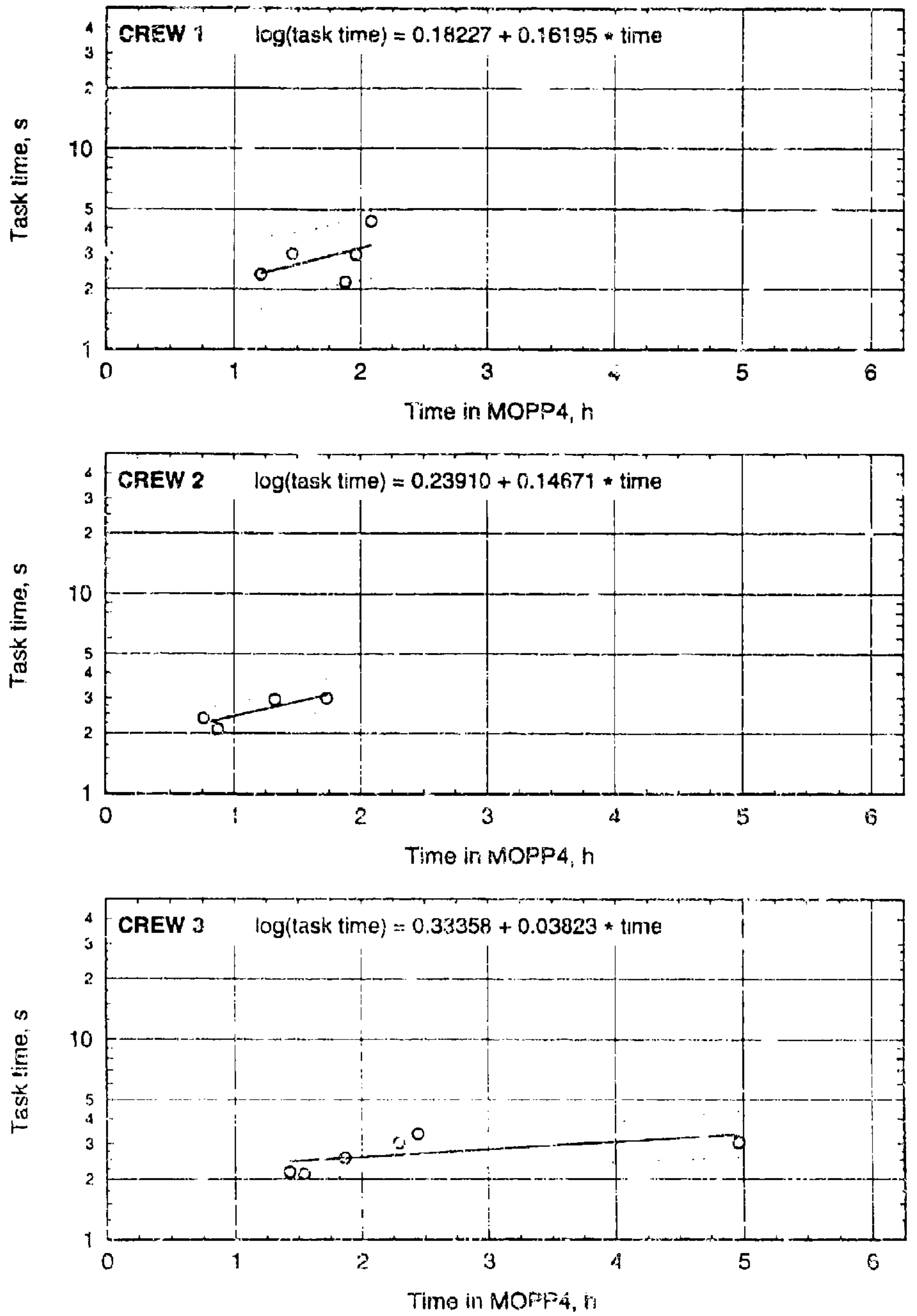


Figure C-117. Task times with regression lines for **last open breech** in MOPP4-S.

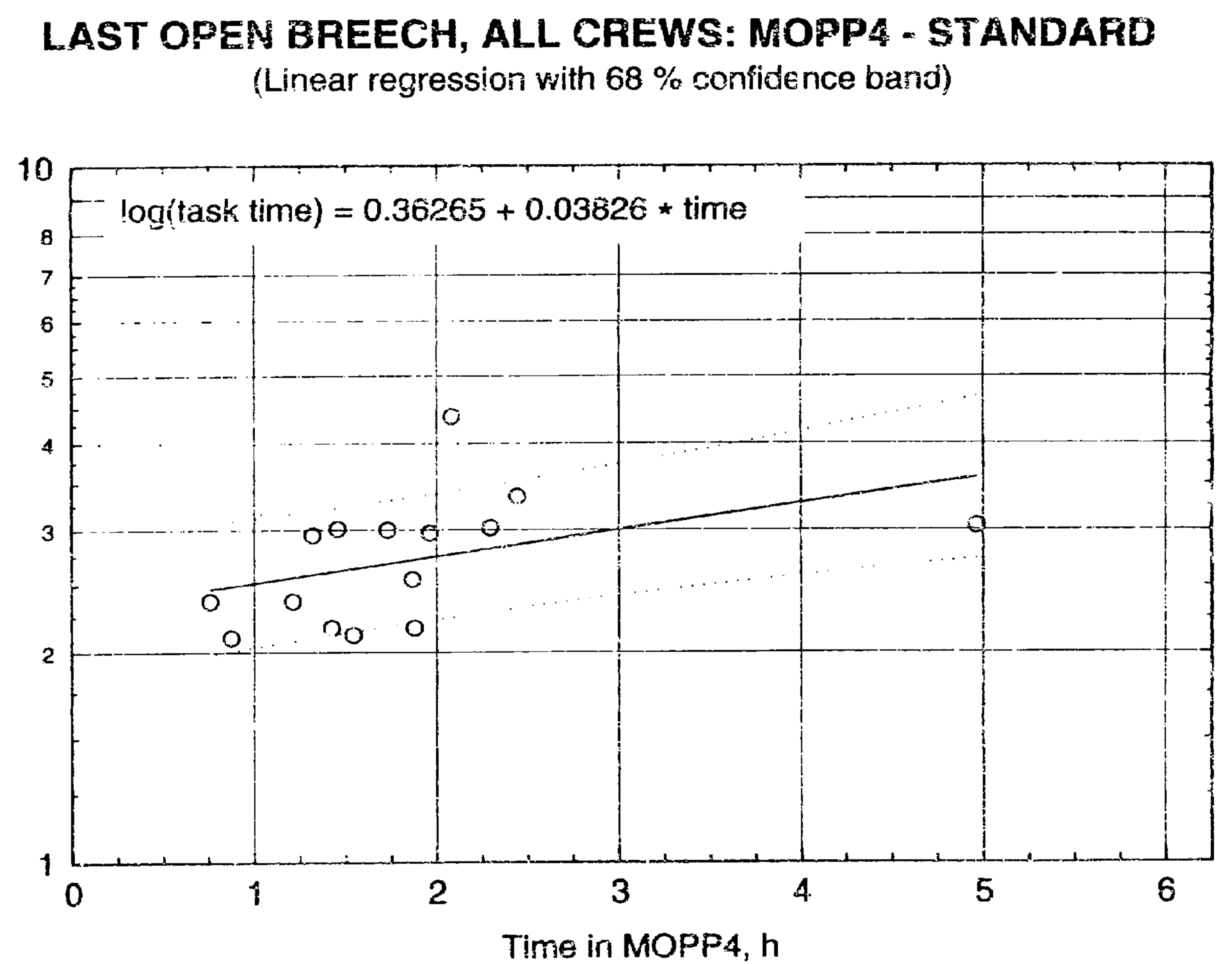


Figure C-118. Aggregate task time data with regression line for **last open breech** in MOPP4-S.

Table C-117. Statistical summary[1] for **last open breech** with crews in MOPP4-S.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	.46060	.41098	.42621	.43361
Number of Observations	5	4	6	15
Total Sum of Squares	.05561	.01703	.03429	.11295
Residual Sum of Squares	.04147	.00424	.02179	.09307
Std. Dev. of Estimate	.11757	.04606	.07381	.08461
R-squared	.25427	.75081	.36447	.17603
Adjusted R-squared	.005[illegible]	.62622	.20559	.11265
Degrees of Freedom (df)	[illegible]	2	4	13
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	1.02288	6.02615	2.29401	2.77728
Prob. Value of F	.38632	.13350	.20444	.11951
Constant	.18227	.23910	.33358	.36265
Standard error	.28018	.07371	.06818	.04786
Slope	.16195	.14671	.03823	.03826
Standard error	.16013	.05976	.02524	.02296
t-ratio	1.01138	2.45482	1.51460	1.66652
prob t	.38632	.13350	.20444	.11951
Correlation Coefficient	.50425	.86650	.60372	.41956

[1]See Section 4 for discussion of regression equations and units.

Table C-118. ANOVA for **last open breech** with crews in MOPP4-S.

	Sum Sq	*DF*	*Mean Sq*
Crew	.00602	2	.10693
Error	.00301	12	.00891

Mean of Dependent Variable	.43361
Number of Observations	15
Total Sum of Squares	.11295
Residual Sum of Squares	.10693
Std. Dev. of Estimate	.09440
R-squared	.05330
Adjusted R-squared	-.10448
Degrees of Freedom (df)	12
Number of Ind Vars (K)	3
F(K-1, df)	.33782
Prob. Value of F	.71989

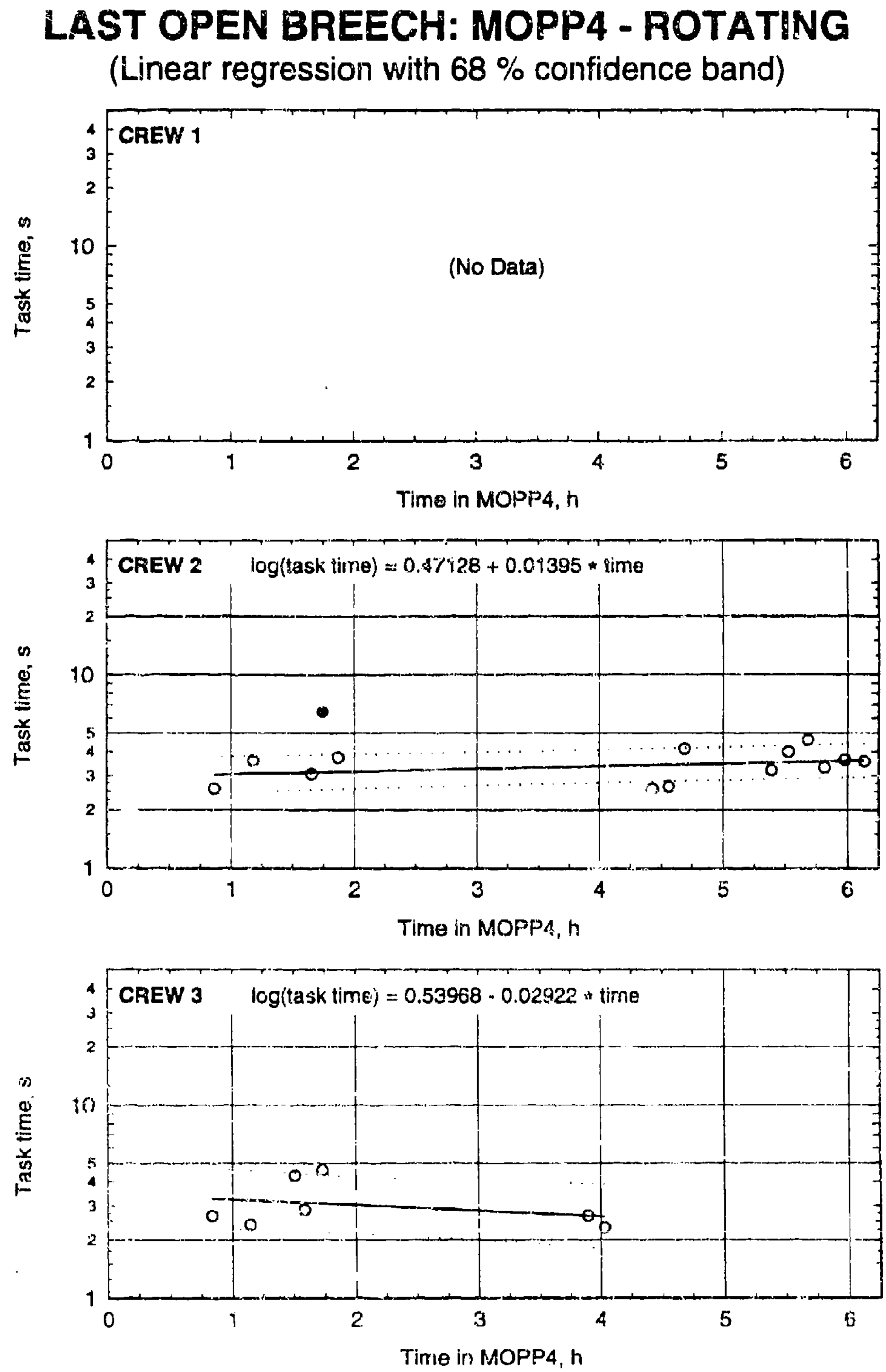


Figure C-119. Task times with regression lines for **last open breech** in MOPP4 R.

LAST OPEN BREECH, CREWS 2 AND 3: MOPP4 - ROTATING

(Linear regression with 68 % confidence band)

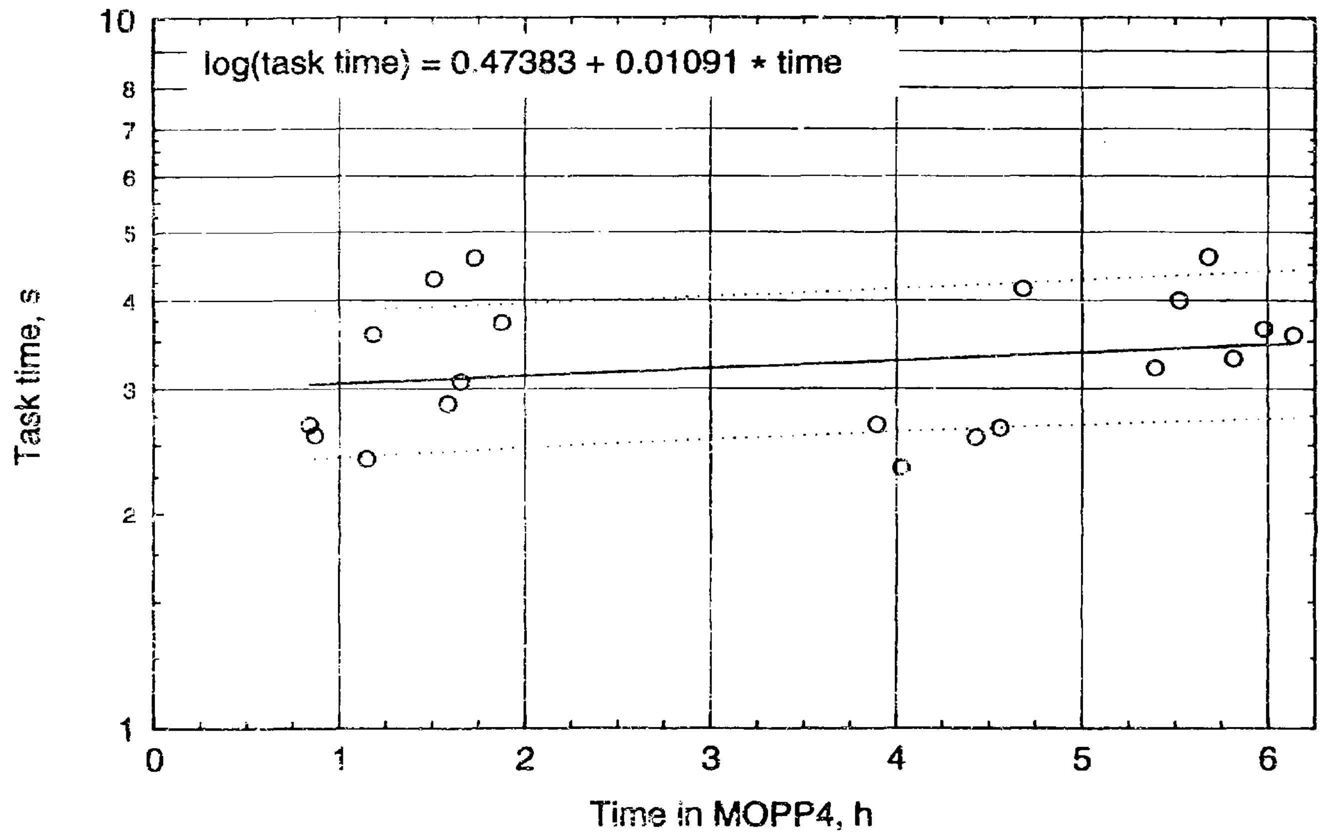


Figure C-120. Aggregate task time data with regression line for **last open breech** in MOPP4-R.

Table C-119. Statistical summary[1] for **last open breech** with crews in MOPP4-R.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	No Data	.52900	.47822	.51122
Number of Observations		13	7	20
Total Sum of Squares		.07758	.08599	.17531
Residual Sum of Squares		.06836	.07731	.16621
Std. Dev. of Estimate		.07883	.12435	.09609
R-squared		.11887	.10099	.05193
Adjusted R-squared		.03877	-.07881	-.00074
Degrees of Freedom (df)		11	5	18
Number of Ind Vars (K)		2	2	2
F(K-1, df)		1.48396	.56167	.98591
Prob. Value of F		.24864	.48733	.33390
Constant		.47128	.53968	.47383
Standard error		.05218	.09452	.04336
Slope		.01395	-.02922	.01091
Standard error		.01145	.03898	.01099
t-ratio		1.21818	-.74945	.99293
prob t		.24864	.48733	.33390
Correlation Coefficient		.34477	-.31779	.22788

[1]See Section 4 for discussion of regression equations and units.

Table C-120. ANOVA for **last open breech** with crews in MOPP4-R.

	Sum Sq	*DF*	*Mean Sq*
Crew	.01173	1	.16358
Error	.01173	18	.00909

Mean of Dependent Variable	.51122
Number of Observations	20
Total Sum of Squares	.17531
Residual Sum of Squares	.16358
Std. Dev. of Estimate	.09533
R-squared	.06691
Adjusted R-squared	.01507
Degrees of Freedom (df)	18
Number of Ind Vars (K)	2
F(K-1, df)	1.29078
Prob. Value of F	.27080

SWAB AND INSPECT: BATTLE DRESS UNIFORM

(Linear regression with 68 % confidence band)

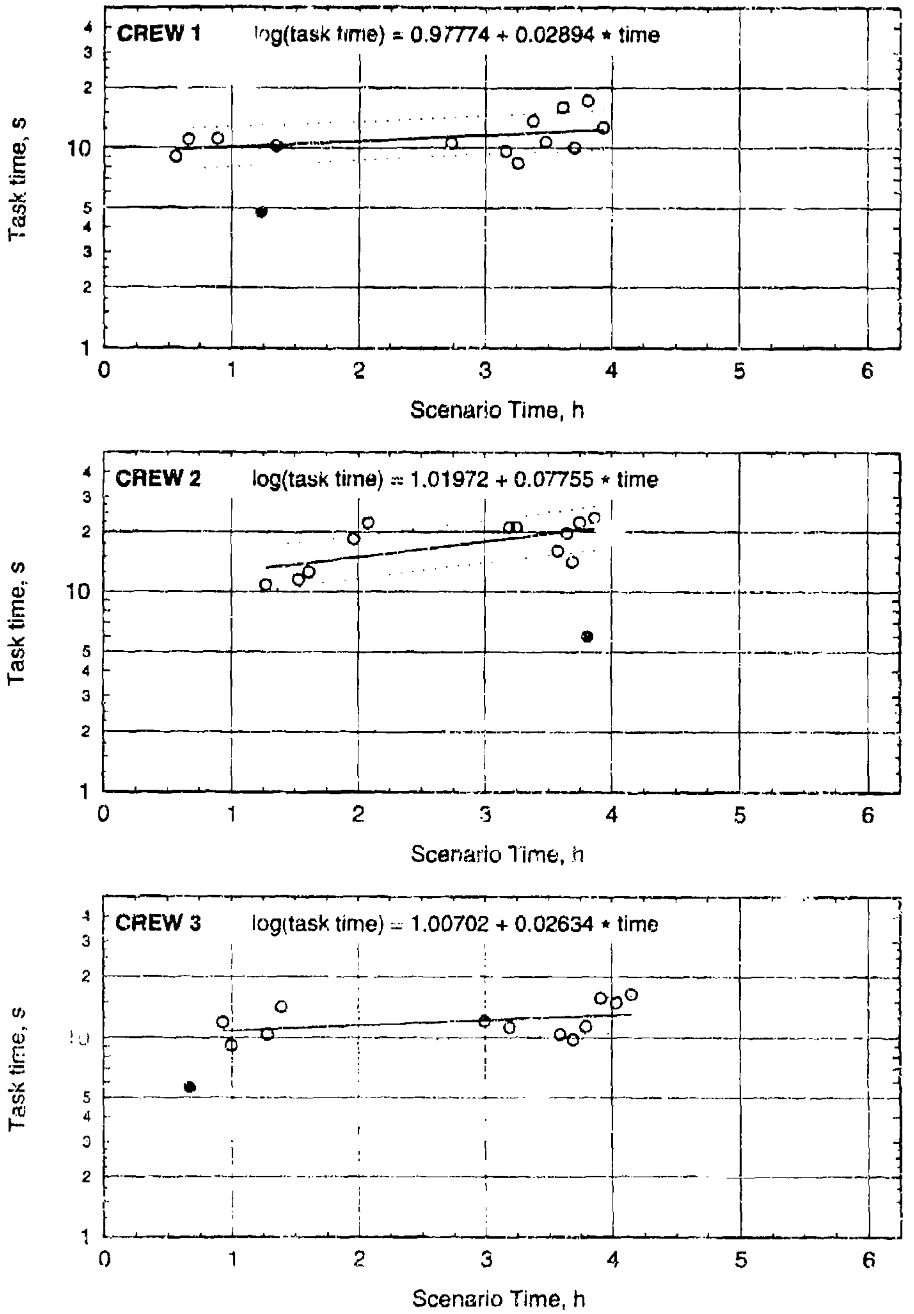


Figure C-121. Task times with regression lines for **swab and inspect** in BDU.

SWAB AND INSPECT, ALL CREWS: BATTLE DRESS UNIFORM

(Linear regression with 68 % confidence band)

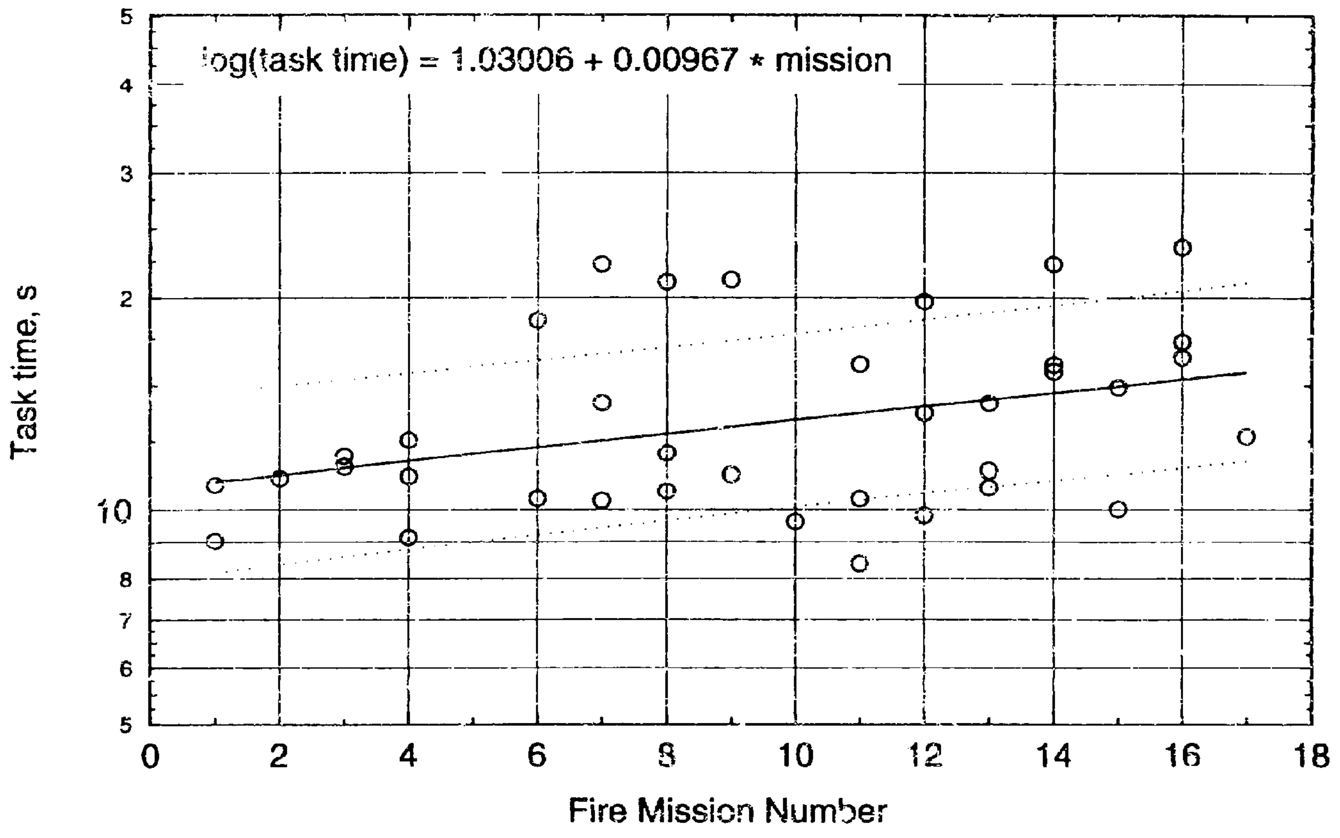


Figure C-122. Aggregate task time data with regression line for swab and inspect in BDU.

Table C-121. Statistical summary[1] for **swab and inspect** with crews in BDU.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	1.05455	1.23579	1.08154	1.12208
Number of Observations	13	12	12	37
Total Sum of Squares	.10358	.16163	.07745	.57685
Residual Sum of Squares	.08681	.09492	.06483	.50262
Std. Dev. of Estimate	.08884	.09743	.08052	.11984
R-squared	.16193	.41277	.16300	.12867
Adjusted R-squared	.08574	.35405	.07930	.10377
Degrees of Freedom (df)	11	10	10	35
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	2.12534	7.02907	1.94748	5.16838
Prob. Value of F	.17283	.02426	.19307	.02925
Constant	.97774	1.01972	1.00702	1.03006
Standard error	.05816	.08621	.05823	04502
Slope	.02894	.07755	.02634	.00967
Standard error	.01985	.02925	.01887	.00425
t-ratio	1.45786	2.65124	1.39552	2.27341
prob t	.17283	.02426	.19307	.02925
Correlation Coefficient	.40240	.64247	.40374	.35870

[1]See Section 4 for discussion of regression equations and units.

Table C-122. ANOVA for **swab and inspect** with crews in BDU.

	Sum Sq	*DF*	*Mean Sq*
Crew	.23417	2	.34267
Error	.11709	34	.01008

Mean of Dependent Variable	1.12208
Number of Observations	37
Total Sum of Squares	.57685
Residual Sum of Squares	.34267
Std. Dev. of Estimate	.10039
R-squared	.40595
Adjusted R-squared	.37101
Degrees of Freedom (df)	34
Number of Ind Vars (K)	3
F(K-1, df)	11.61724
Prob. Value of F	.00014

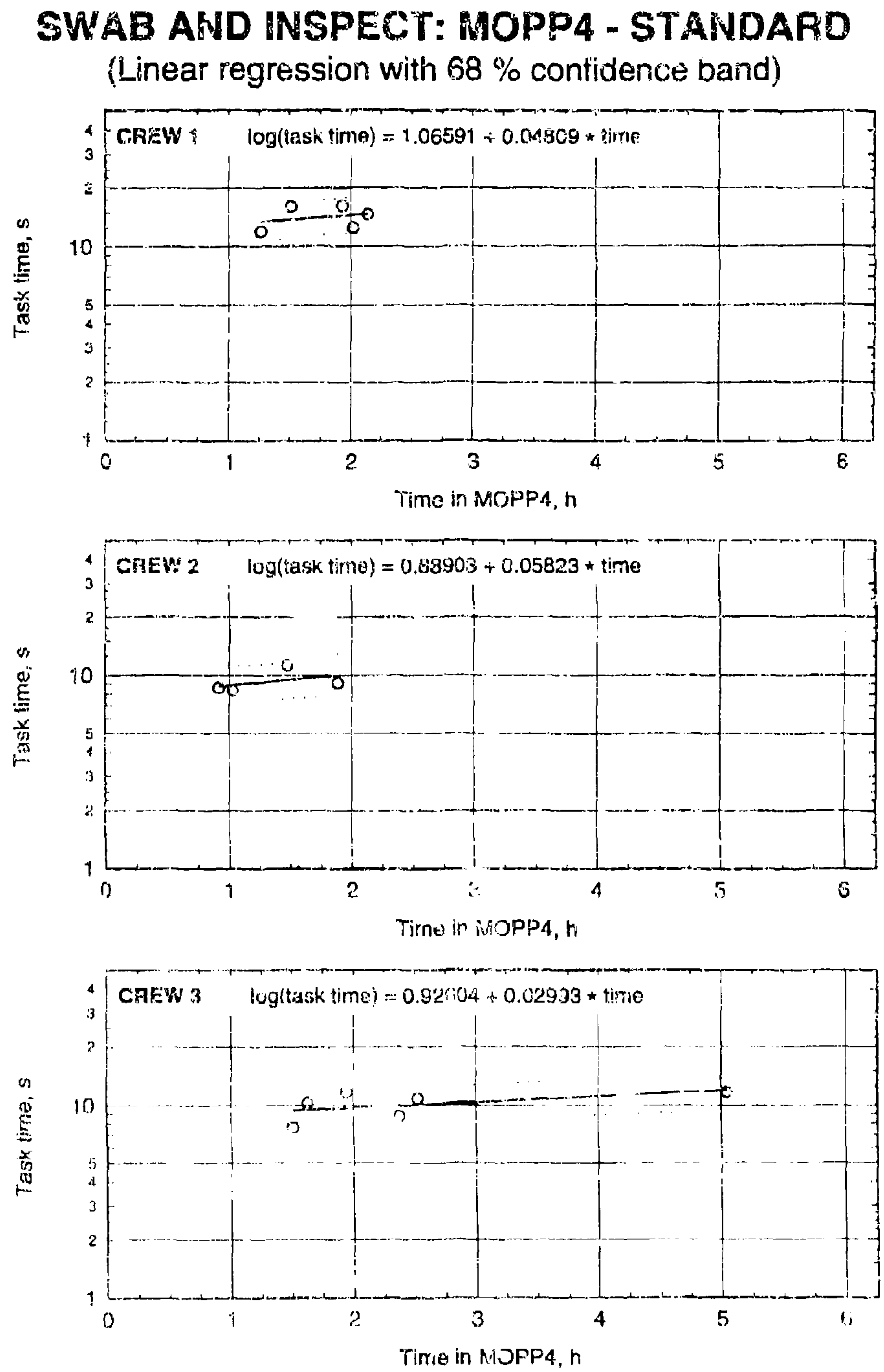


Figure C-123. Task times with regression lines for **swab and inspect** in MOPP4-S

SWAB AND INSPECT, ALL CREWS: MOPP4 - STANDARD

(Linear regression with 68 % confidence band)

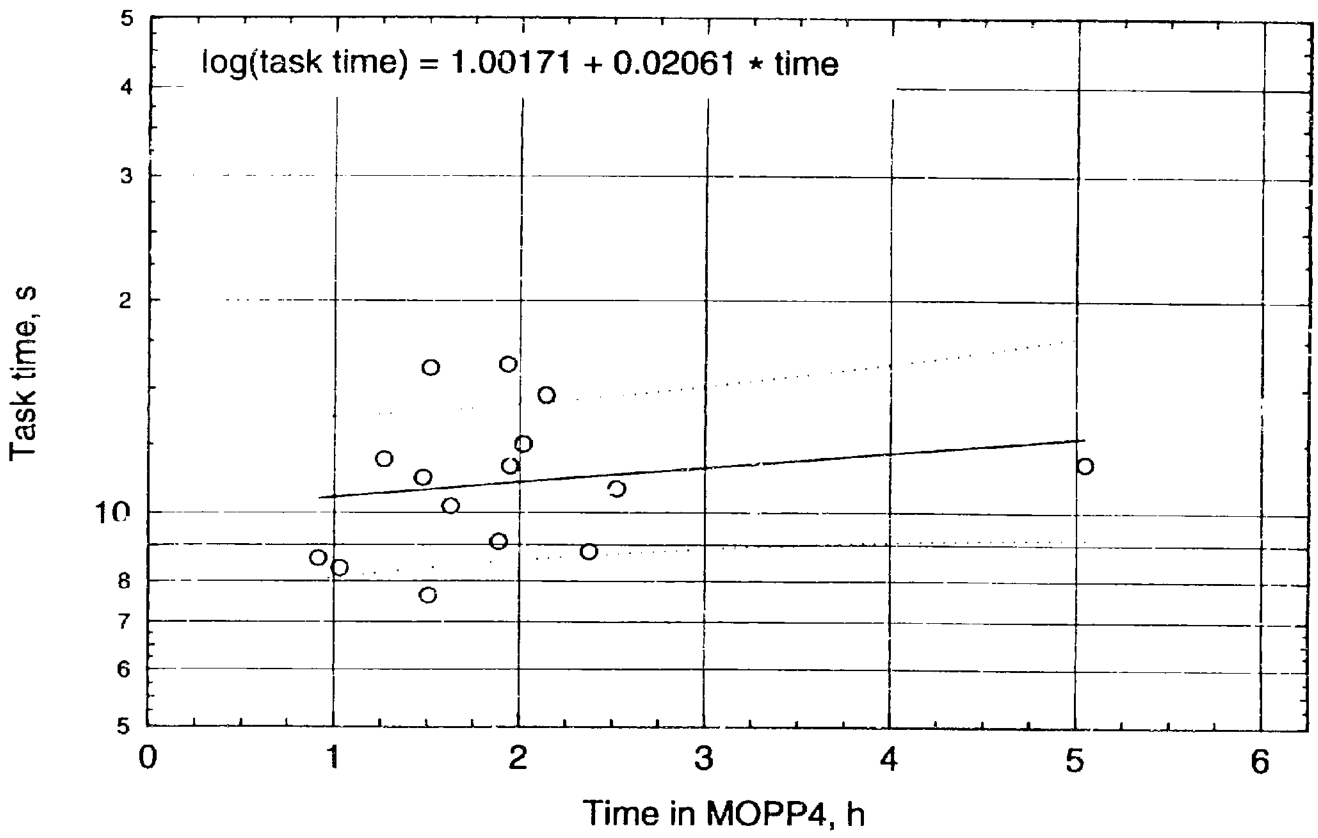


Figure C-124. Aggregate task time data with regression line for **swab and inspect** in MOPP4-S.

Table C-123. Statistical summary[1] for **swab and inspect** with crews in MOPP4-S.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	1.15125	.96633	1.00099	1.04183
Number of Observations	5	4	6	15
Total Sum of Squares	.0[illegible]532	.00998	.02729	.14526
Residual Sum of Squares	.01[illegible]07	.00796	.01963	.13964
Std. Dev. of Estimate	.06849	.06309	.07005	.10364
R-squared	.08149	.20208	.28074	.03869
Adjusted R-squared	-.22468	-.19688	.10093	-.03526
Degrees of Freedom (df)	3	2	4	13
Number of Ind Vars (K)	2	2	2	2
F(K-1, df)	.26616	.50652	1.56128	.52316
Prob. Value of F	.64153	.55047	.27960	.48231
Constant	1.06591	.88903	.92604	1.00171
Standard error	.16821	.11310	.06645	.06159
Slope	.04809	.05823	.02993	.02061
Standard error	.09321	.08182	.02395	.02849
t-ratio	.51591	.71170	1.24951	.72330
prob t	.64153	.55047	.27960	.48231
Correlation Coefficient	.28547	.44953	.52985	.19669

[1]See Section 4 for discussion of regression equations and units.

Table C-124. ANOVA for **swab and inspect** with crews in MOPP4-S.

	Sum Sq	*DF*	*Mean Sq*
Crew	.09267	2	.05259
Error	.04633	12	.00438

Mean of Dependent Variable	1.04183
Number of Observations	15
Total Sum of Squares	.14526
Residual Sum of Squares	.05259
Std. Dev. of Estimate	.06620
R-squared	.63796
Adjusted R-squared	.57762
Degrees of Freedom (df)	12
Number of Ind Vars (K)	3
F(K-1, df)	10.57273
Prob. Value of F	.00225

SWAB AND INSPECT: MOPP4 - ROTATING

(Linear regression with 68 % confidence band)

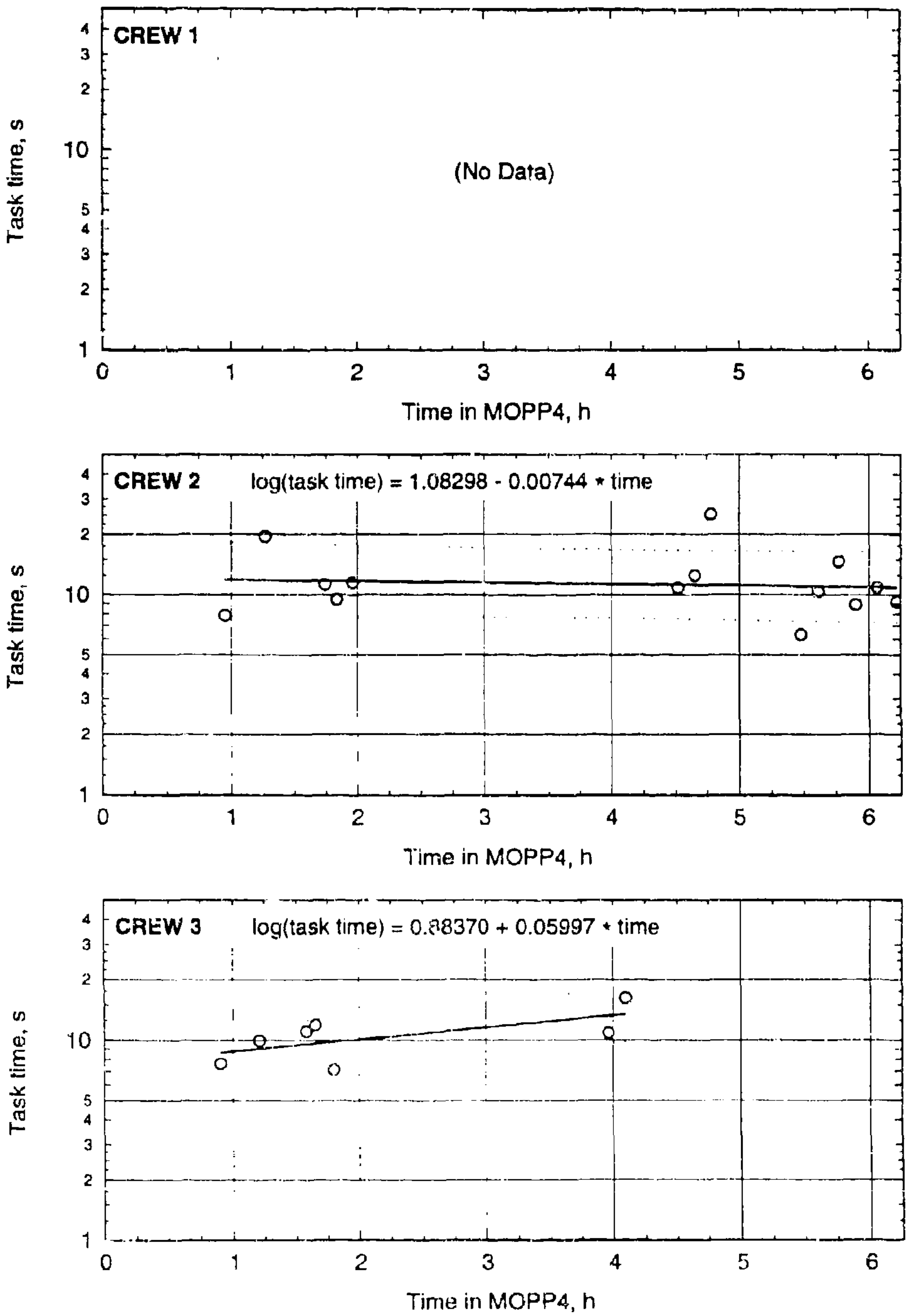


Figure C-125. Task times with regression lines for **swab and inspect** in MOPP4-R.

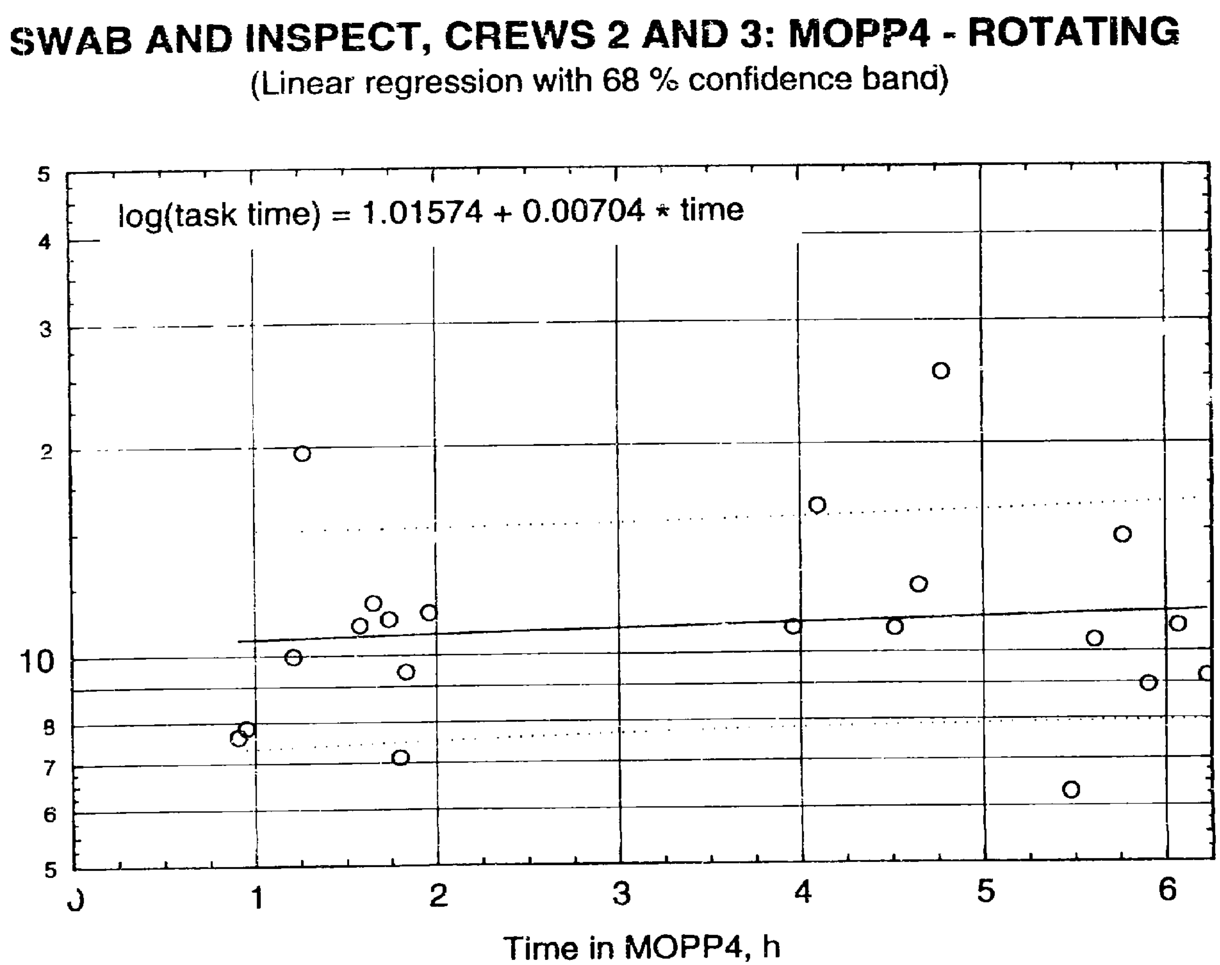


Figure C-126. Aggregate task time data with regression line for **swab and inspect** in MOPP4-R.

Table C-125. Statistical summary[1] for **swab and inspect** with crews in MOPP4-R.

	Crew 1	*Crew 2*	*Crew 3*	*Aggregate*
Mean of Dependent Variable	No Data	1.05283	1.01398	1.03988
Number of Observations		14	7	21
Total Sum of Squares		.31031	.08733	.40468
Residual Sum of Squares		.30739	.05071	.40074
Std. Dev. of Estimate		.16005	.10071	.14523
R-squared		.00940	.41926	.00974
Adjusted R-squared		-.07315	.30311	-.04238
Degrees of Freedom (df)		12	5	19
Number of Ind Vars (K)		2	2	2
F(K-1, df)		.11386	3.60973	.18690
Prob. Value of F		.74162	.11587	.67037
Constant		1.08298	.88370	1.01574
Standard error		.09907	.07842	.06421
Slope		-.00744	.05997	.00704
Standard error		.02204	.03156	.01629
t-ratio		-.33743	1.89993	.43232
prob t		.74162	.11587	.67037
Correlation Coefficient		-.09695	.64750	.09870

[1]See Section 4 for discussion of regression equations and units.

Table C-126. ANOVA for **swab and inspect** with crews in MOPP4-R.

	Sum Sq	*DF*	*Mean Sq*
Crew	.00705	1	.39764
Error	.00705	19	.02093

Mean of Dependent Variable	1.03988
Number of Observations	21
Total Sum of Squares	.40468
Residual Sum of Squares	.39764
Std. Dev. of Estimate	.14467
R-squared	.01741
Adjusted R-squared	-.03431
Degrees of Freedom (df)	19
Number of Ind Vars (K)	2
F(K-1, df)	.33665
Prob. Value of F	.56858

APPENDIX D
DISCUSSION OF TASK TIME OUTLIERS

The measured distribution of times for a given task will inevitably contain *outliers*, that is, points that deviate an unreasonable amount from the mean of the distribution. If the task times are normally distributed, then the significance of a deviation can be judged quantitatively with a statistical test. Outliers are identified by setting a probability threshold below which values are unlikely to belong to a normal distribution of measured times for the given sample. Alternatively, observations regarding extraneous factors affecting the data may be used to designate outliers.

Outliers may result from observer error or crew error. As many observer errors as possible have been eliminated from the data with redundancy and consistency checks. However, since not all data had redundant measurements, there are likely to be undetected observer errors present in the final data. Further elimination of such errors would require analysis of the videotape record of the exercise. This procedure would be labor intensive, essentially requiring a complete remeasurement of all event times to check for errors. For the present analysis, we assume that observer errors do not make dominant contributions to the variance of task times. We will note special cases in which observer error can be eliminated by defining outliers.

In addition, an outlier may result from a procedural error or an outright blunder by one or more crew members. Outliers of this type are infrequent when the crew is well trained and using well designed and maintained equipment. Although such outliers may be an important part of crew performance analysis if the errors adversely impact crew survival, they are not of primary importance when general performance degradation from a battlefield stressor is the central issue, as it is in the present study of artillery crew performance.

For the present analysis, outliers are plotted in figures with separate symbols for future reference but are not included in regression analyses or the analysis of variance.

Field notes taken by observers during the exercise are an important source of information to identify outliers caused by crew errors. For example, on a few rounds (out of 581), the ram was not sufficiently v rous to properly seat the projectile in the chamber of the howitzer. On these occasions, the ram was repeated at the command of the Chief of Section. On one occasion with the crew in MOPP4, no one noticed an ineffective ram and the projectile subsequently fell out of the breech onto the ground as the projectile handlers started to moved away. Such errors are always corrected by the crew and were usually noted in writing by the observers. When the correction process requires substantial time, the resulting task time outlier can be correlated with the written comments by the observers.

Appendix B presents a transcription of notes taken by the observers who logged task time

data during the exercise. Although these notes are certainly not exhaustive, they frequently explain obvious outliers.

Finally, and sometimes most importantly, consideration must be given to maintaining consistency in the task time being measured. In certain instances, procedural changes caused significant variation in task time. The dominant cause is the loss of crew members during the MOPP4 exercises and the subsequent adjustment of task load among crew members. Whenever possible, outlier limits are chosen to maintain consistency in the task time being measured for an individual crew member. With this choice, calculated performance degradation is relevant to individual tasks and does not reflect the higher order effects of crew interactions under stress. This latter issue is important but not addressed in this report.

RELAY ORDERS.

Examination of the aggregate plot for the **relay orders** task time for all three crews in BDU shows a minimum time of about 20 s for the oral relay of orders to the crew. With an outlier criterion of 17 s, Crew 3 shows an outlier at 15 s on Fire Mission 17. Observer notes indicate that the crew was "rushing to a fault", apparently having thrown caution to the winds for the last fire mission of the day. The longer times for BDU tail off in the 30 to 35 s range with no apparent outliers.

A criterion of 25 s is used to define short-time outliers for MOPP4-S to eliminate the measured values for Fire Missions 5 and 6 for Crew 1. Observer notes indicate that a new crew member moved to the RTO position after Fire Mission 4 "sounds faster". This criterion flags one value for Crew 3 as an outlier as well. The longer times in MOPP4-S extend to the 40 to 50 s range with no apparent outliers.

The times of about 60 s in MOPP4-R for Fire Mission 8 of Crew 2 and Fire Mission 3 of Crew 3 are potential long-time outliers. Observer comments indicate that these missions were "ragged" and "disorganized" at the start but indicate no specific anomalies, so the values are retained in this analysis. A criteria of 17 s gives no short-time outliers in MOPP4-R. Neither the aggregate plot for MOPP4-R nor the observer comments provide a basis for designating short-time outliers. The **relay orders** task times for MOPP4-R have a large variance but there is seems to be no objective way to declare outliers.

BEGIN SET DEFLECTION.

The Gunner for Crews 1 and 2 used the electronic GDU to obtain the deflection setting since his typical start times are within a few seconds of the start of calling out orders, too soon for the Chief of Section to have provided the data verbally. The high value of about 20 s for the **begin set deflection** task time for Fire Mission 12 of Crew 2 in BDU is probably due to observer

error. The Gunner for Crew 3 seems to have waited for verbal deflection data, since his times of 15 to 20 s for **begin set deflection** are near the end of the verbal orders. A criterion of 13 s is chosen to exclude the outlier for Crew 2 and much of the data for Crew 3. The times for the late fire missions of Crew 3 are short enough that the Gunner must have begun using the GDU. There are no apparent short time outliers in BDU.

Criteria of 15 s and 13 s for long time outliers is used for MOPP4-S and MOPP4-R, respectively. Most of the outliers for both MOPP4-S and MOPP4-R are due to loss of the Assistant Gunner. Outliers result when the Gunner chooses to set the elevation before he sets the deflection. Although this change of task order is an important consideration for understanding and modeling crew operations with loss of crew members, it is a confounding variable when the focus is on the degradation of a fixed task. The present analysis focuses on the degradation of fixed tasks, so times resulting from changing task order are considered as outliers. (The data would support future analysis regarding loss of crew members.) As in BDU, there are no apparent short time outliers in MOPP4.

SET DEFLECTION.

The **set deflection** task was measured from the time that the gunner reached for the small crank on the mechanical register for the deflection setting to the time that he reached for the large crank/wheel to accomplish the traverse. During this interval, the gunner brings the mechanical register to the correct integer deflection setting. Several measurements for this task were quite short, one value for Crew 3 in BDU being less than 1.5 seconds. This short time is more likely to be caused by observer error than by a remarkably swift action by the gunner. The likely explanation is that observer inattention caused a late recording of the *set deflection* event. Presumably, the observer comes to attention after recording *set deflection* and gets a better measurement of the task ending time (the start of the *traverse tube/level bubble* event). The result is an underestimation of the task time for **set deflection**. By inspection of the aggregate plot for **set deflection** for all crews, we choose a minimum time of 2.5 s below which measured times are flagged as outliers due to measurement error. For BDU fire missions, there are no obvious candidates for long-time outliers. Most times are in the 3 to 9 s range.

Many of the **set deflection** task times in MOPP4 are also below 10 s, indicating that MOPP4 is not a major impediment for this task. On the other hand, Fire Mission 6 for Crew 2 in MOPP4-S is about 30 s. According to observer comments, this fire mission came in while the crew was just emerging from the shade after completing a psychological questionnaire. The task time may be long because of a measurement error or a procedural flaw caused by the unusual mission start. It is considered an outlier for the present analysis.

Crew 2 in MOPP4-R completed all 17 fire missions; however, beginning with Fire

Mission 12, the crew operated with no Assistant Gunner because of loss of personnel. Beginning with Fire Mission 12, the Gunner performed the tasks of both the Gunner and Assistant Gunner position. The same thing happened for Crew 3 in MOPP4-R for Fire Missions 8 and 9. During these missions, some **set deflection** times were normal and others exceeded 20 s. Inspection of the timelines for these fire missions shows that the abnormally long times are caused by variations in the order in which the Gunner performed the double set of tasks. The longer times caused by abnormal task ordering are designated as outliers for the present analysis.

A maximum task time of 17.5 s for **set deflection** is used to define outliers for all postures. In addition to the outliers discussed above, this criterion flags the measured time of Fire Mission 1 for Crew 3 in MOPP4-S as an outlier although nothing appears in the field notes (Appendix B) to indicate an abnormal procedure for this fire mission.

This detailed discussion regarding outliers for **set deflection** task times illustrates the considerations we use to set criteria for outliers for all tasks. Similar procedures are used for the rest of the tasks even if only an abbreviated discussion is presented.

TRAVERSE TUBE.

Analysis of the **traverse tube** task is complicated by two factors. First, for Crew 1, **traverse tube** includes only the time for the gross azimuthal motion of the tube. This task is referred to a **traverse tube I**. For Crews 2 and 3, the measured task time also includes the fine adjustment at the end of the traverse and any pause to wait for the gross motion of the tube elevation to end. This task is referred to as **traverse tube II**. Second, in MOPP4, loss of crew members after resupply (Fire Missions 8 and higher) usually forced the Gunner to take on the Assistant Gunner tasks as well as his own. In this case, the order of tasks was not always the same.

There are no apparent outliers for the **traverse tube I** task time (Crew 1) in BDU or MOPP4-S. For **traverse tube II**, an outlier criterion of 30 s for Crews 2 and 3 in BDU gives one outlier for each crew. The Crew 2 data indicates that this limit should be relaxed in MOPP4-S. A value of 38 s is used for both MOPP4-S and MOPP4-R. This value results in only one outlier for Fire Missions 1 to 7, but eliminates most of the data for Missions 8 to 17 when the Assistant Gunner was missing. A short-time criterion of 10 s is set for **traverse tube II** in BDU to flag the value for Fire Mission 12 of Crew 2 as an outlier. This criterion also flags Fire Mission 7 of Crew 3. For MOPP4, the short-time criterion is increased to 13 s to flag the task times for Fire Missions 10 and 12 as outliers for Crew 2 in MOPP4-R. These low values are probably due to observer confusion regarding the order of tasks being done by the Gunner. There are no short-time outliers for MOPP4-S.

BEGIN SET ELEVATION.

The considerations for definition of task time outliers for the **begin set elevation** task are the same as those for the **begin set deflection** task. Examination of the BDU data for **begin set elevation** shows that the Assistant Gunner for Crew 2 consistently to the elevation angle from the GDU. Based on the Crew 2 data, values of -5 s and +10 s are chosen for the lower and upper outlier criteria in BDU. This choice eliminates much of the Crew 1 and Crew 3 data. The same lower limit is used in MOPP4. The upper limit of 15 s for MOPP4 is based primarily on the Crew 2 data in MOPP4-R. It results in complementary designation of outliers relative to the **begin set deflection** task for the late fire missions when the Gunner was doing both his tasks and those of the Assistant Gunner. The time for the task he chose to do first is retained and the second is designated as an outlier. The retained values for both BDU and MOPP-4 correspond to a single crew member responding to the GDU to begin setting the elevation with no other competing task.

SET ELEVATION.

The **set elevation** task is similar to the **set deflection** task and is subject to the same measurement error on the short side from observer inattention. Inspection of aggregate plots for the three crews in BDU shows that the same minimum time of 2.5 s gives a good separation between the apparent lower edge of the task time distribution and the short-time outliers. The same criterion is used for MOPP4-S where there are no apparent short-time outliers. For MOPP4-R, the short-time criterion is increased to 3.5 s to flag the task time for Fire Mission 5 of Crew 2 as an outlier. This value is more than 2 standard deviations faster than the mean for Crew 2 in BDU, probably due to observer error.

A maximum time of 17.5 s gives a good definition of outliers on the long side for all postures. **Set elevation** times apparently include variance from the same task order differences as **set deflection** during the times when the Gunner is doing the Assistant Gunner tasks in addition to his own.

ELEVATE TUBE.

A criterion of 35 s is used to define outliers on the long side for the **elevate tube** task time in BDU and MOPP4-S. This criterion is chosen to eliminate the measurement for Fire Mission 8 of Crew 3 in MOPP4-S. This mission had no Assistant Gunner and, furthermore, observer error is suspected since the **elevate tube** task time overlaps the *safety check* event. The criterion also flags the measured time for Fire Mission 7 of Crew 2 in BDU as an outlier. The evidence for a problem with this fire mission is that the timeline indicates that the **elevate tube** task delayed the safety check well after the howitzer had been primed.

The same criterion of 35 s is used to define long-time outliers in MOPP4-R. This value eliminates the measurements for Fire Missions 15 and 16 for Crew 2. Crew 2 operated with no Assistant Gunner from Fire Mission 12 onward. The measured values for Fire Missions 13, 14, and 17 are retained for the present analysis even though there is some uncertainty whether the observer clearly distinguished which task the Gunner was performing. This 35 s criterion also flags the measurement for Fire Mission 1 as an outlier for this crew. According to observer notes, the Assistant Gunner "elevated twice" on this mission.

There are no apparent short-time outliers for **elevate tube** in BDU. A minimum time of 13 s is used to define outliers in MOPP4-S and MOPP4-R mainly to eliminate the measurement for Fire Mission 2, Crew 3 in MOPP4-S. Examination of the timeline and the task time for **set elevate** for this mission indicates that the observer was late starting the *elevate tube* event. The criterion flags the measured values for Fire Mission 6 of Crew 1 in MOPP4-S and Fire Mission 3 of Crew 3 in MOPP4-R as an outliers on the short side, probably due to observer error as well.

BEGIN FIRST LOAD.

A criterion of 19 s defines short-time outliers for the **begin first load** task time for all postures. The two resulting outliers in BDU are attributed to procedural anomalies. There are no short-time outliers in MOPP4. A criterion of 90 s defines long-time outliers for all postures. The only outlier occurs for Fire Mission 3 of Crew 3 in MOPP4-R. This mission began with the crew "bickering".

LOAD PROJECTILE.

Criteria of 1 s and 9 s define short- and long-time outliers, respectively, for the **load projectile** task times for BDU and MOPP4-S. For BDU there is one outlier, probably due to observer error. For MOPP4-S, Crew 2 has an outlier for Fire Mission 6 that is unexplained. Crew 3 has an outlier for Fire Mission 1 caused by an ineffective ram that allowed the projectile to fall out of the breech onto the ground.

Criteria of 2.4 s and 9 s define short- and long-time outliers, respectively, for MOPP4-R. The long-time outliers for MOPP4-R are also caused by ineffective rams that had to be repeated. The short-time criterion is increased to flag the shortest time for Fire Mission 17 of Crew 2 as an outlier, probably due to observer error.

LOAD FIRST POWDER.

The **load first powder** task time data tends to have a large variance with the crews in BDU and MOPP4-R. A long-time criterion of 20 s in BDU flags one outlier for Fire Mission 15 of Crew 2. Observer comments indicate "late powder" for this round. There are no apparent

long-time outliers in MOPP4-S or MOPP4-R and, likewise, no short-time outliers for any posture.

LOAD FIRST PROJECTILE AND POWDER.

The task time for **load first projectile and powder** includes the time for the **load first powder** task and so has the same tendency for a large variance for Crews 2 and 3. Crew 1 has less variance. A long-time criterion of 20 s for BDU produces only one outlier for Crew 2, as before. A long-time criterion of 30 s for MOPP4-S is used to flag the times for Fire Missions 5 and 7 as outliers for Crew 2. Using the same criterion for MOPP4-R flags the time for Fire Mission 15 of Crew 2. Observer comments indicate irregularities in procedure for these fire missions. No short-time outliers are evident for any posture.

LOCK BREECH AND PRIME.

Criteria of 2 s and 10 s are used to define short- and long-time outliers, respectively, for the **lock breech and prime** task time for both BDU and MOPP4-S. Crews 1 and 3 in BDU have one outlier each in the 15 to 20 second range. These excessively long times were caused by failure of the Loader to recognize that the breech had not been fully locked so that, in turn, the primer could not be latched (presumably a safety feature). The short time outlier for Crew 1 in BDU is probably observer error. Crews 1 and 2 had no outliers for this task in MOPP4-S. Crew 3 had many. The first, during Fire Mission 4, was the result of a dropped primer. The rest of the outliers encompass all of the rounds for Fire Missions 6, 7, and 8. After medical personnel removed the regular Loader from the exercise, the inexperienced replacement was unwrapping primers during this task interval rather than having them prepared in advance.

The criterion for long-time outliers with crews in MOPP4-R is increased to 15 s to accommodate the relatively slow performance of Crew 2. The one measured time that is flagged as an outlier on Fire Mission 7 was caused by an incorrect belief by the Loader that the primer was not latched properly.

FIRE.

The criteria for short- and long-time outliers for the **fire** task time are 1.0 s and 5.3 s, respectively, for crews in BDU. Times shorter than 1 s are likely due to observer error. The data for Crew 3, however, shows that short times in the 1.0 to 1.5 s range are reasonable. The situation for long-time outliers is more complicated. The only long-time outlier for Crew 1 occurred when the No. 1 Cannoneer misplaced his lanyard after the second round of the last fire mission. Crew 3 shows more variance in the later fire missions but no obvious basis for declaring outliers.

Crew 2, on the other hand, shows numerous outliers in BDU with a long tail of task times

exceeding 10 s. These outliers were misfires caused by an inexperienced No. 1 Cannoneer with insufficiently vigorous pulls on the lanyard. After a misfire, the No. 1 Cannoneer usually pulled another time or two and succeeded in firing the howitzer, causing the outliers. Once (Fire Mission 8), it was necessary to call a safety check and replace the primer. The long-time outlier criterion of 5.3 seconds is chosen to eliminate as many as possible of the misfires for Crew 2 without cutting into the distribution of times for Crews 1 and 3.

After his poor performance on Monday in BDU, the No. 1 Cannoneer for Crew 2 perfected his technique and had no more misfires on Wednesday or Friday in MOPP4. Criteria of 1 s and 8 s are used to define short- and long-time outliers, respectively, for both MOPP4-S and MOPP4-R.

OPEN BREECH.

There are no apparent short-time outliers for the **open breech** task time for any posture. A criterion of 3.5 s is used to define outliers in BDU. With this criterion, there are no outliers for Crew 3 and only 1 for Crew 1. On the other hand, Crew 2 in BDU has many outliers. These outliers are probably due to the high misfire rate of the Loader for the BDU missions as discussed for the **fire** task time since the breech is opened by the Loader immediately after the howitzer is fired. There is no similar problem for the same Loader in MOPP4-S when there were no misfires.

A criterion of 5 s is used to define long-time outliers for MOPP4-S and MOPP4-R. The resulting outliers for Crew 2 in MOPP4-R are due to start up problems with a new loader rotated into the position on Fire Mission 6.

SWAB CHAMBER.

Criteria of 3.5 s and 9 s define short- and long-time outliers, respectively, for the **swab chamber** task time in BDU. The only short-time outlier is on the last fire mission of Crew 3, a mission that was rushed excessively by the crew. The long-time outlier for Crew 1 corresponded to a major delay in bringing the next projectile to the breech. That for Crew 2 is probably an observer error since the end of the task is later than the *load* event.

For MOPP4 data, the short-time criterion is raised to 4 s to pick up a single outlier for Crew 2 in MOPP4-R, probably a result of observer error. The long-time criterion is increased to 15 s; there are no apparent long-time outliers in MOPP4.

CHECK SIGHT.

The aggregate plot for the **check sight** task for all crews in BDU shows an apparent minimum of about 2.5 s to perform the task. A criterion of 2 s is taken to define outliers on the

short side for all postures. There are no obvious outliers on the long side with crews in either BDU or MOPP4. As discussed in Section 3.3, the **check sight** task was ill-defined from the vantage point of the observer. We analyze only the average task time per round for each fire mission and have little confidence in the significance of even this result.

BEGIN RELOAD.

There are no apparent short-time outliers for the **begin reload** task time for either BDU or MOPP4 data. A criterion of 20 s for long-time outliers in MOPP4 is chosen to flag two outliers for Crew 2 in MOPP4-S. This choice is based primarily on retaining all values for Crews 1 and 3 in MOPP4-S. It is clear that the variance on this task time increases greatly in MOPP4.

RELOAD POWDER.

There are no apparent short-time outliers for the **reload powder** task time for either BDU or MOPP4 data. For BDU, a long-time criteria of 10 s is chosen to flag one outlier for Fire Mission 15 of Crew 2. Observer notes indicate "late powder" for Round 1 but no other comment.

A criterion of 10 s is used to flag long-time outliers for the MOPP4 data. The worst outliers occur for Crew 2 in MOPP4-S for Fire Missions 4 to 6. The crew was operating with 7 members for these missions and the Loader was walking back to the powder tent to get the powder bag rather than having it brought to him as usual. Observer comments indicate that some of the other outliers for MOPP4-S and MOPP4-R were caused by poorly wrapped powder bags that had to be adjusted by the Loader. Although, this rewrapping adds to the overall mission time, it is considered a change of task and the corresponding data is not included in the present analysis of task performance degradation.

The choice of 10 s as the criteria is based mostly on the clear separation of outliers for Crew 3 in MOPP4-R. The choice is less obvious if it were based on the same crew in MOPP4-S. The MOPP4-S data of Crew 3 is not used to make the choice since Crew 3 is the only crew in MOPP4-S rather than BDU on the first day of the record trials.

RELOAD PROJECTILE AND POWDER.

There are no apparent short-time outliers for the **reload projectile and powder** task for any posture. A long-time criterion of 15 s is used for both BDU and MOPP4 using considerations similar to those for the **reload powder** task.

LAST OPEN BREECH.

There are no apparent short-time outliers for the **last open breech** task time for any posture. A long-time criterion of 4.5 s flags many of the Crew 2 measured values as outliers for the same reasons explained for the **open breech** task. A long-time criterion of 5 s for the MOPP4 data results in one outlier for Crew 2 in MOPP4-R.

SWAB AND INSPECT.

A criterion of 7 s is used to flag short-time outliers for the **swab and inspect** task time in BDU. There is one such outlier for each crew. There are no relevant observer comments for these outliers; however, the outliers are self-evident from the plots. There are no apparent long-time outliers in BDU.

There are no apparent outliers, either short or long, in MOPP4.

APPENDIX E
PHYSIOLOGICAL DATA FOR CREWMEMBERS

The crewmember physiological data plotted in this Appendix were recorded with the Biomedical Field Safety Monitor (BFS ,, a telemetric, personnel monitoring system developed for the P^2NBC^2 Program by the Walter Reed Army Institute of Research (WRAIR). Collection of data for this exercise was managed by COL Daniel Redmond, M.D., U.S. Army, Department of Behavioral Biology at WRAIR. The data files used to generate the plots contained herein were provided courtesy of COL Redmond.

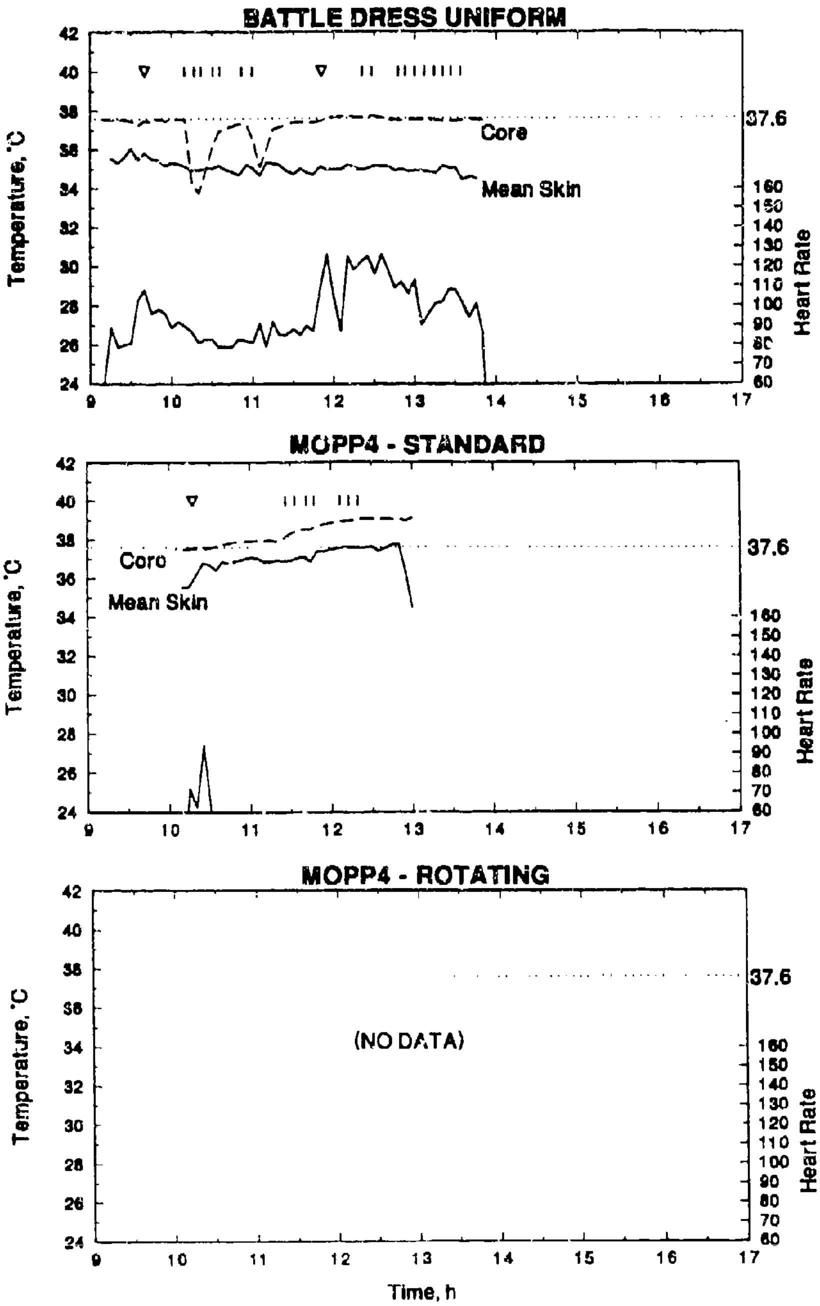
This Appendix contains one page for each participant in the exercise. Each page is headed by the Participant Identification (PID) number and crew position of the individual. Generally, there are three plots for each crewmember, one each for the scenarios in BDU, MOPP4-S, and MOPP4-R. Crew 1 (PIDs 10 through 19) has data for only 2 scenarios since it did not carry out a scenario with regimented rotation of positions.

Each plot provides the time dependence of the crewmember's core temperature and mean skin temperature according to the lefthand scale and his heart rate according to the righthand scale. The data consists of 5 minute averages for each quantity. There is one time series in the data files for heart rate and one for core temperature. These time series are plotted with no additional processing.

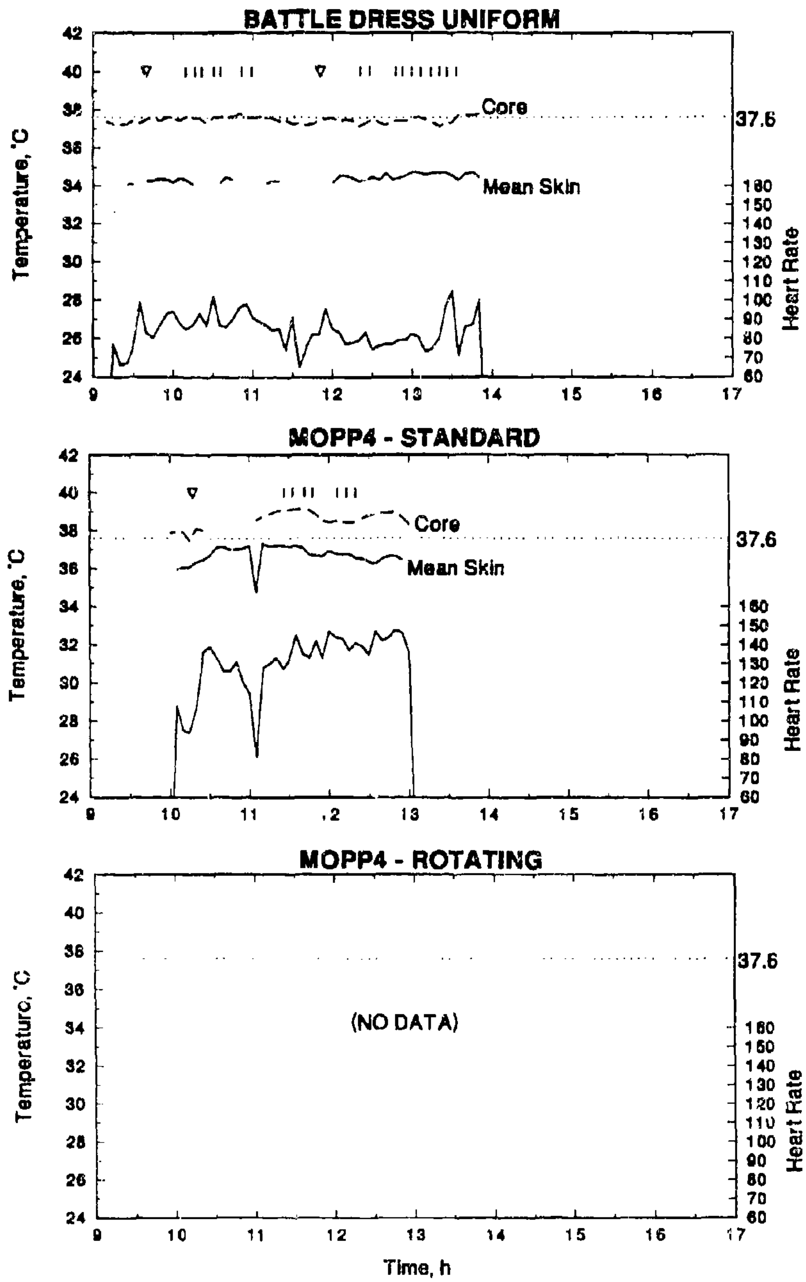
There are skin temperature series for three sensors in the data files, labelled ST1, ST2, and ST3. The second sensor, ST2, had relatively low values (26 to 28 °C) with frequent dropouts and is not used here. The skin temperature plots in this appendix show the mean of the other two sensors. These sensors also had occasional dropouts and anomalous readings at the beginning and ends of data intervals. To minimize the impact of these spurious readings, skin temperature values less than 34 °C are eliminated from the data before averaging.

Finally, for mission context, each plot contains markers for the *move to firing point* events (inverted triangles) before and after resupply and for the start of each fire mission (vertical hash marks). The time scales are EDT.

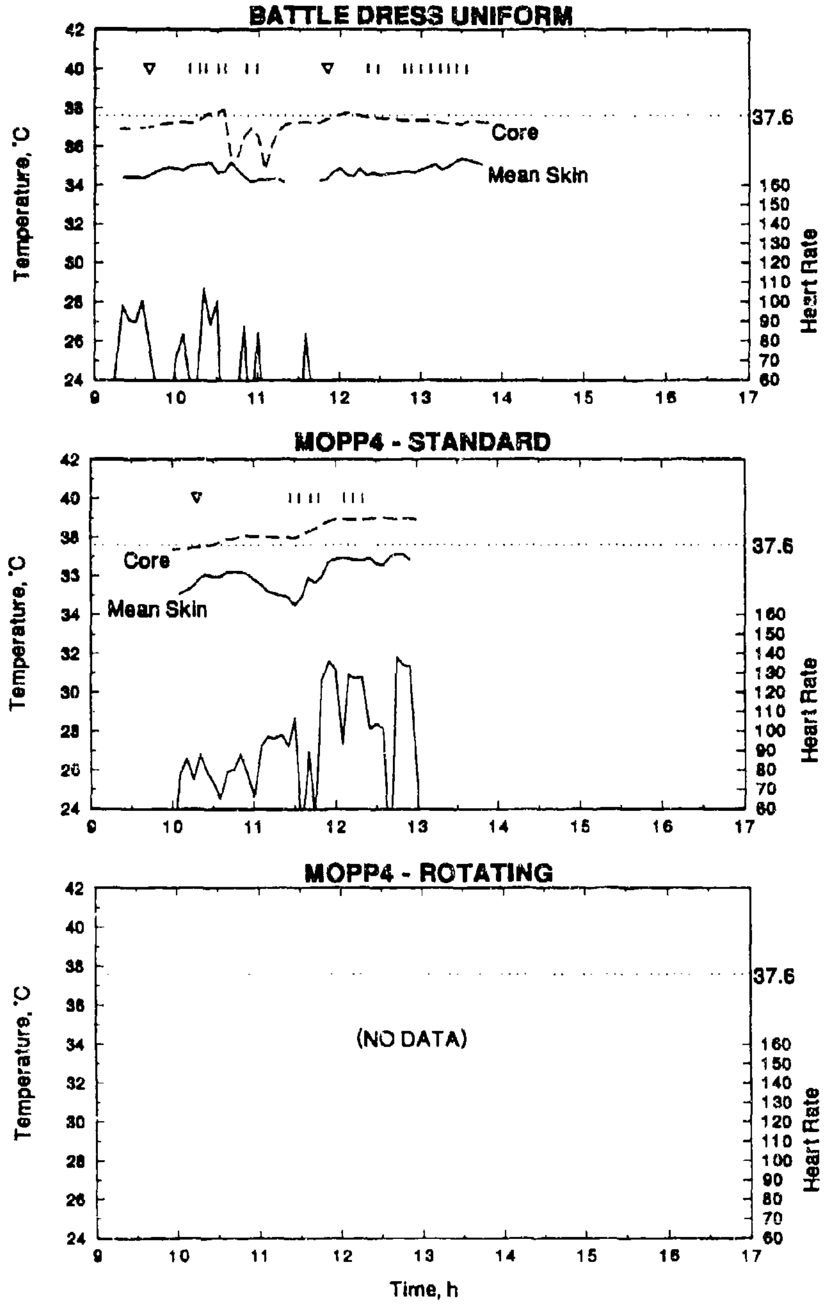
CREWMEMBER 10, CHIEF OF SECTION



CREWMEMBER 11, GUNNER

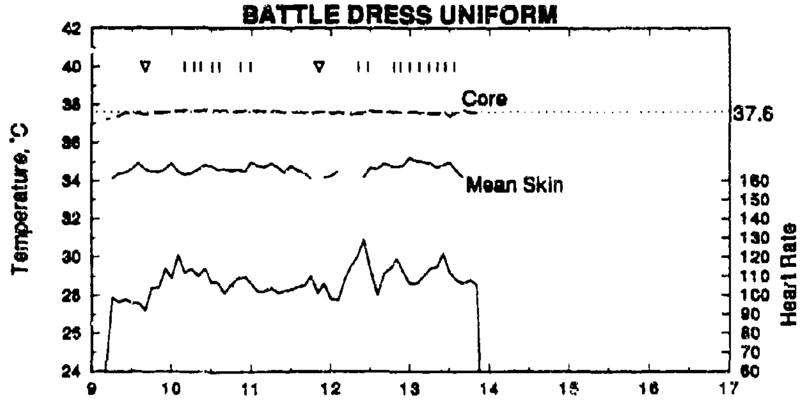


CREWMEMBER 12, ASSISTANT GUNNER

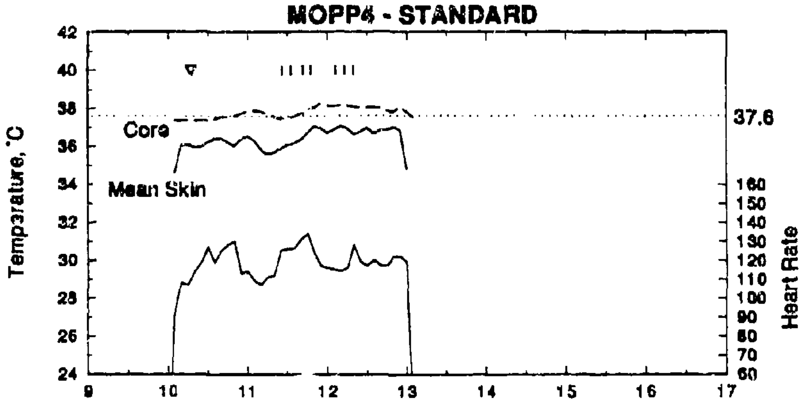


CREWMEMBER 13, LOADER

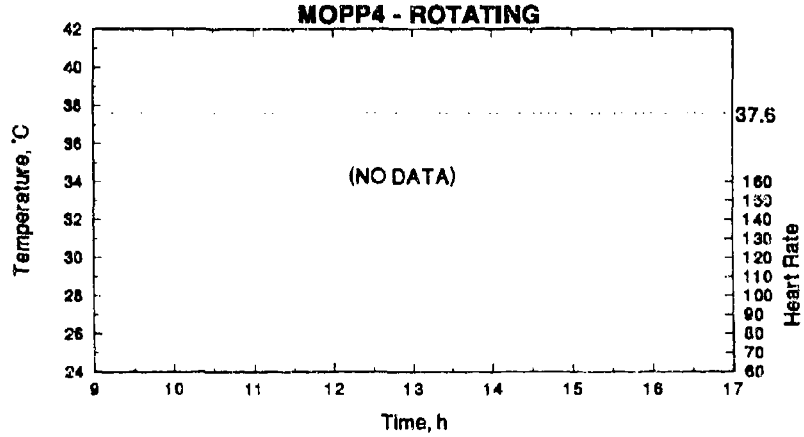
BATTLE DRESS UNIFORM



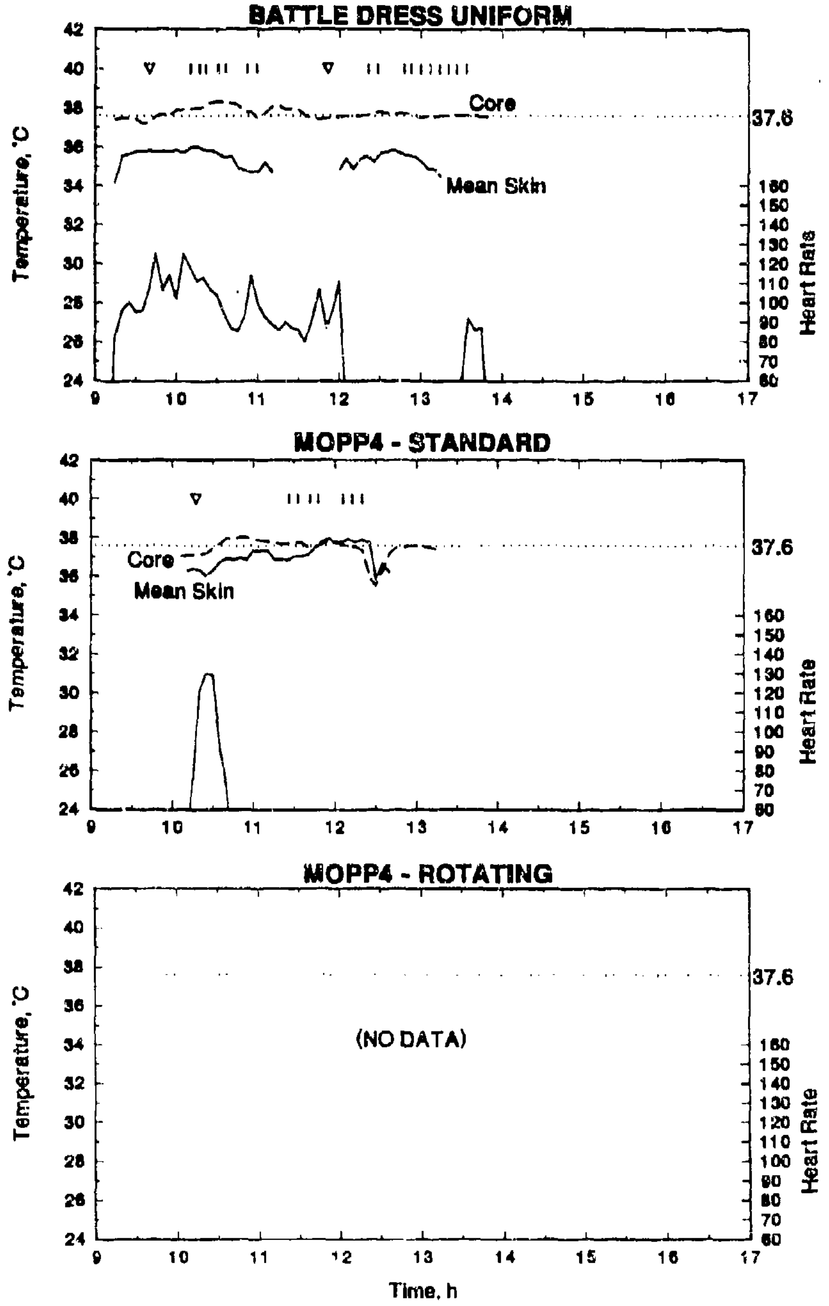
MOPP4 - STANDARD



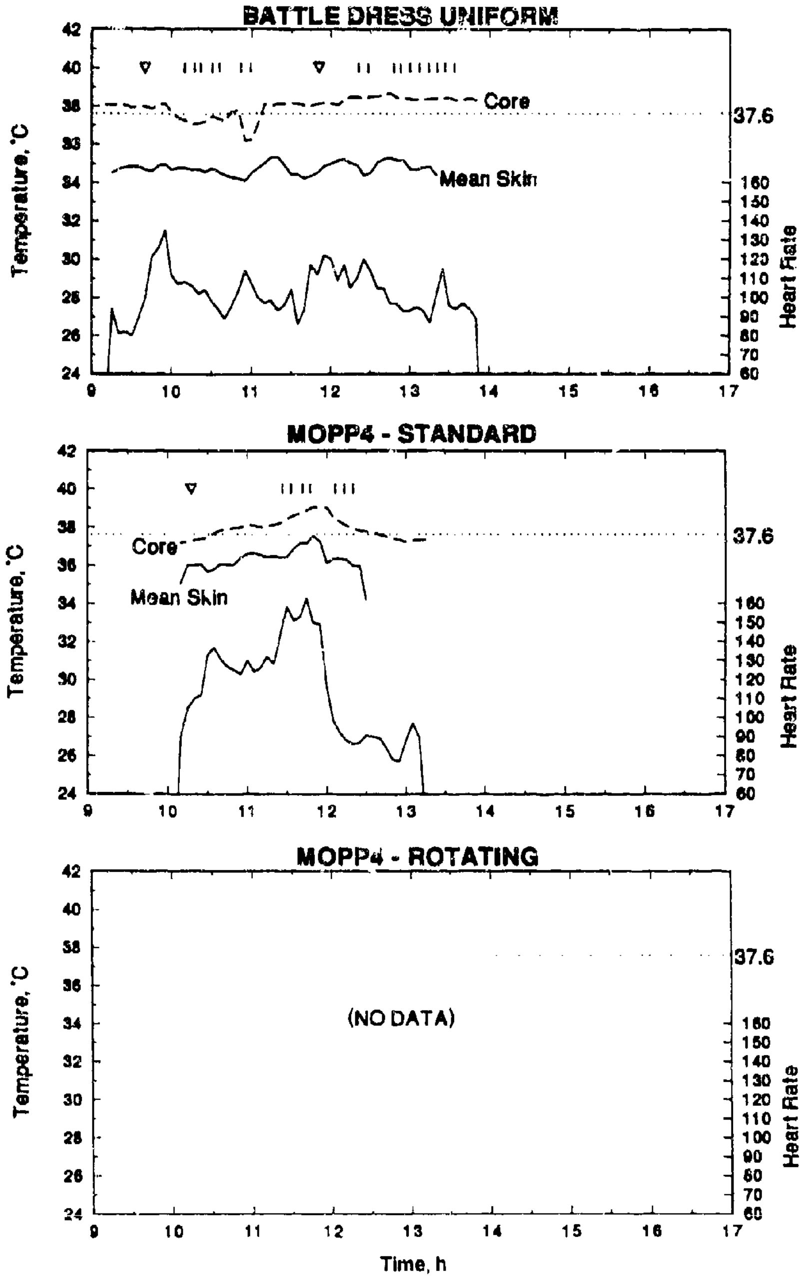
MOPP4 - ROTATING



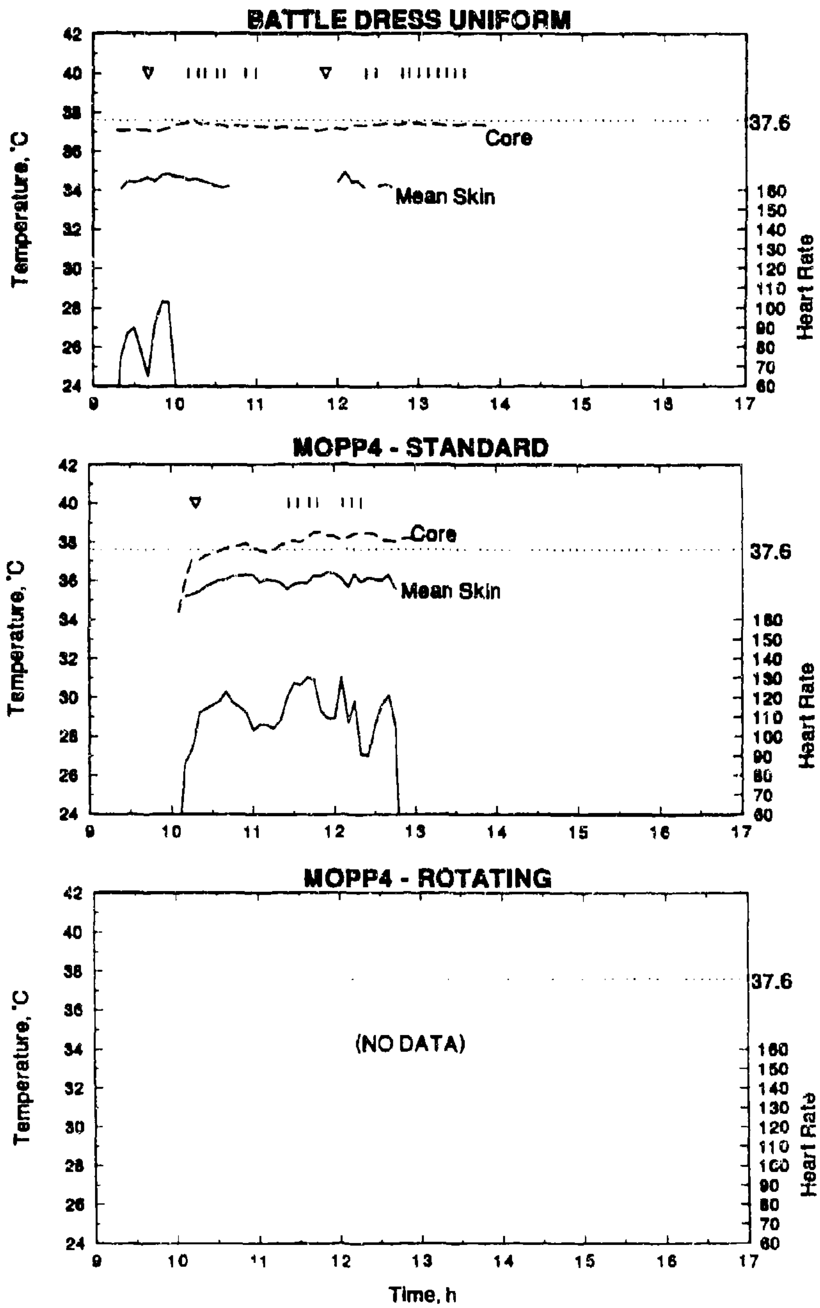
CREWMEMBER 14, #1 AMMO



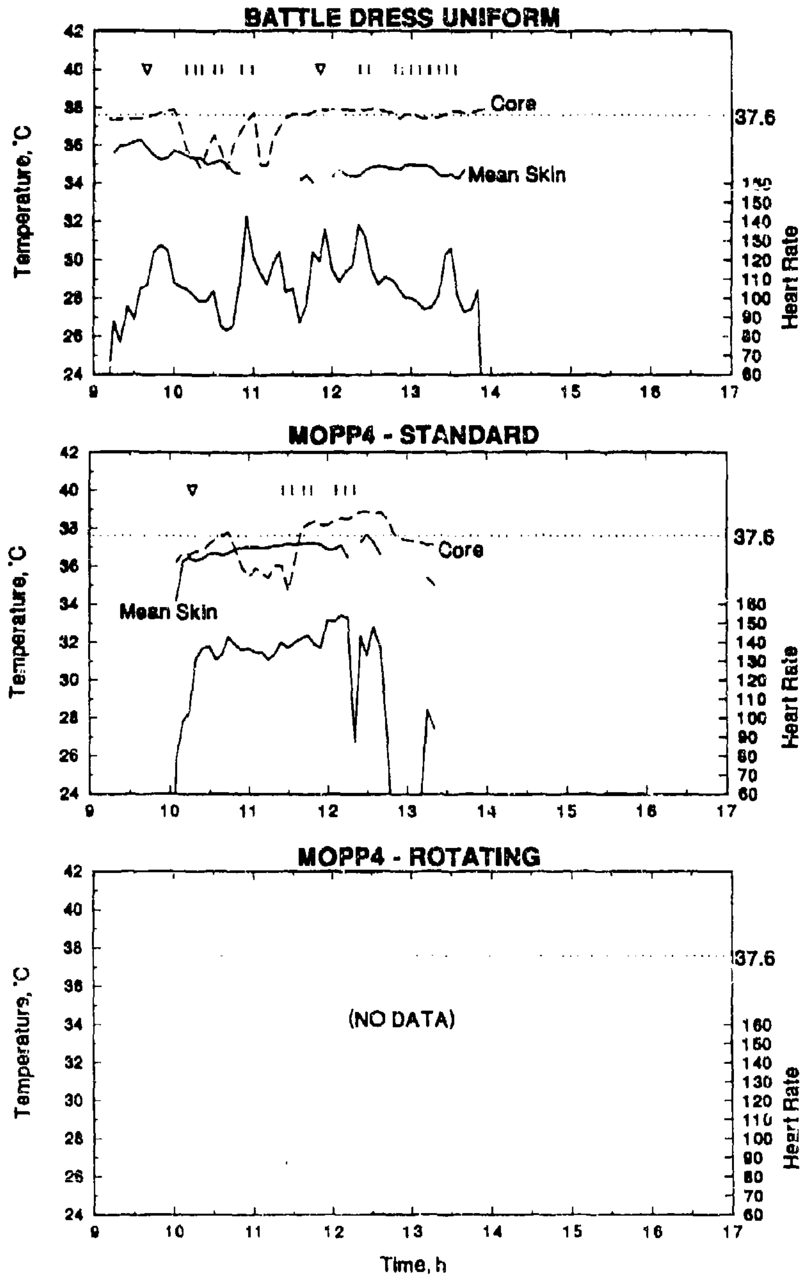
CREWMEMBER 15, #2 AMMO



CREWMEMBER 16, #1 POWDER

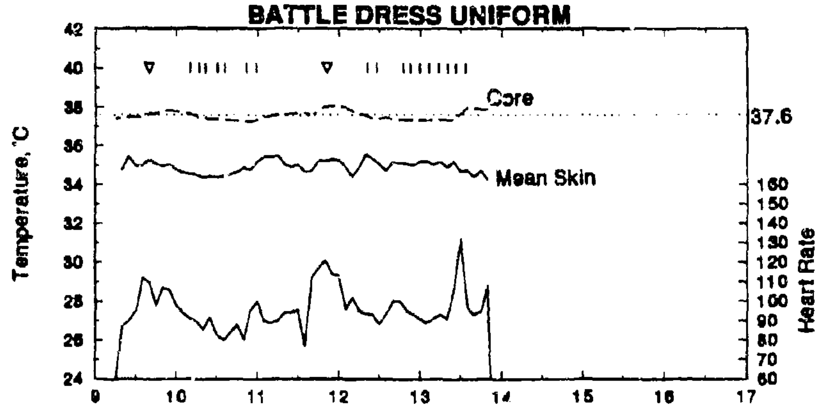


CREWMEMBER 17, #2 POWDER

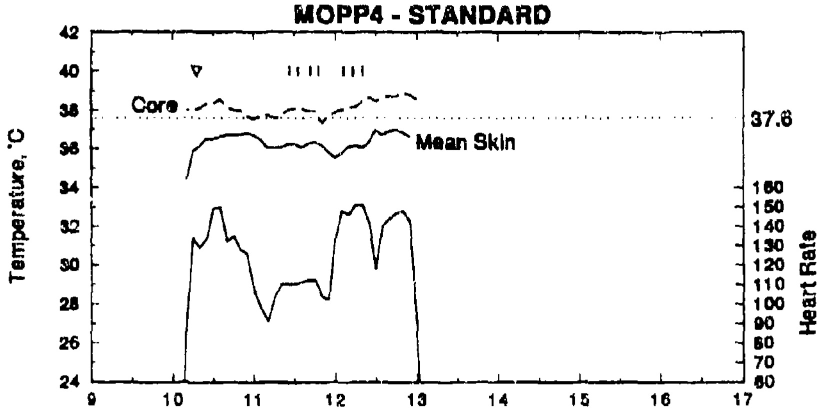


CREWMEMBER 18, RTO

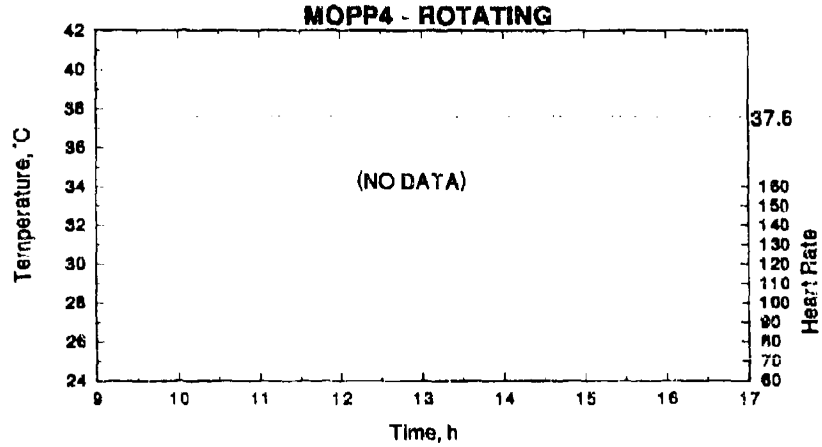
BATTLE DRESS UNIFORM



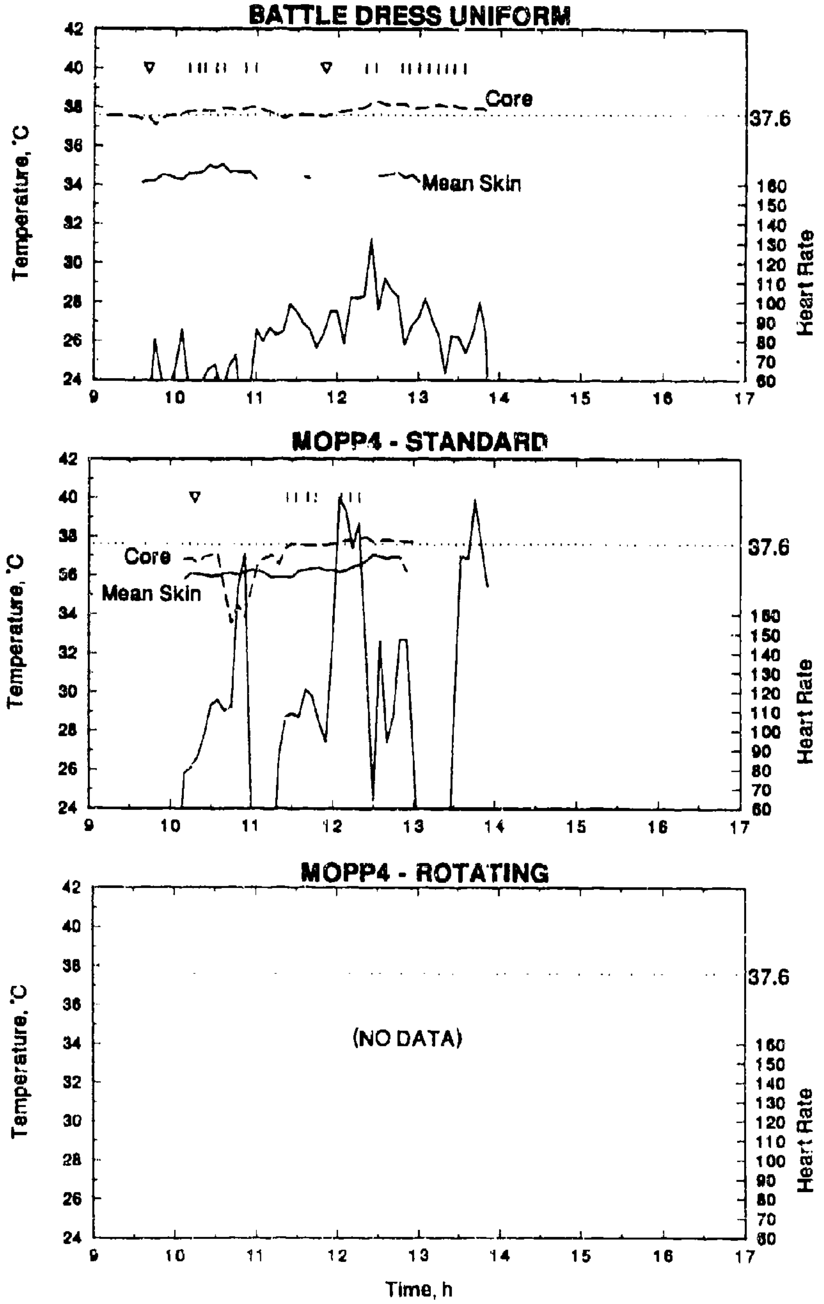
MOPP4 - STANDARD



MOPP4 - ROTATING

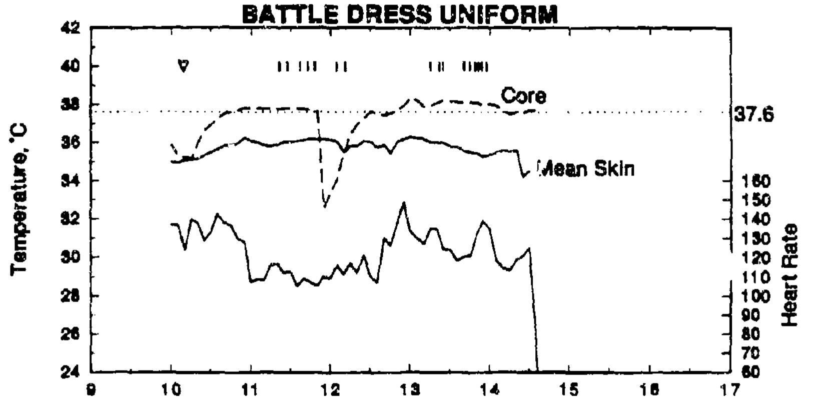


CREWMEMBER 19, DRIVER

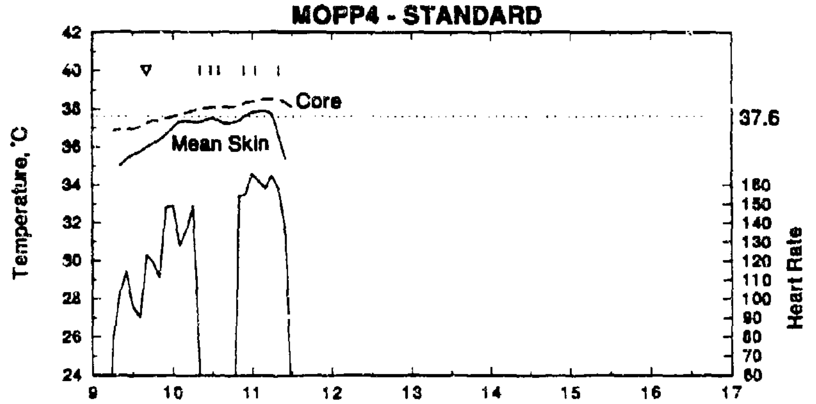


CREWMEMBER 20, CHIEF OF SECTION

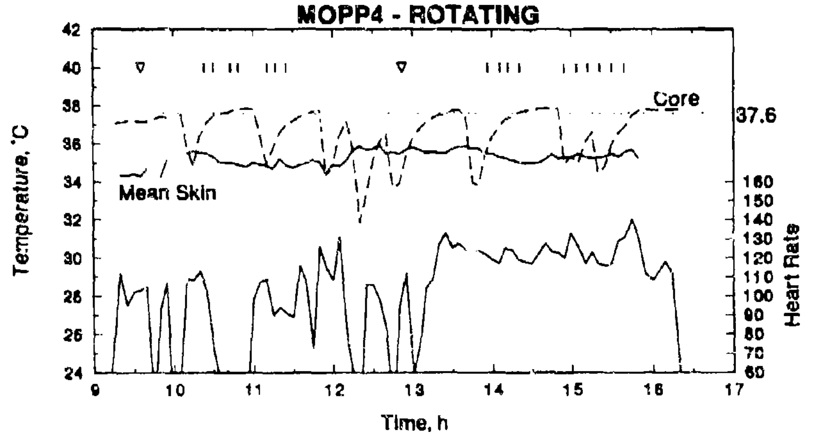
BATTLE DRESS UNIFORM



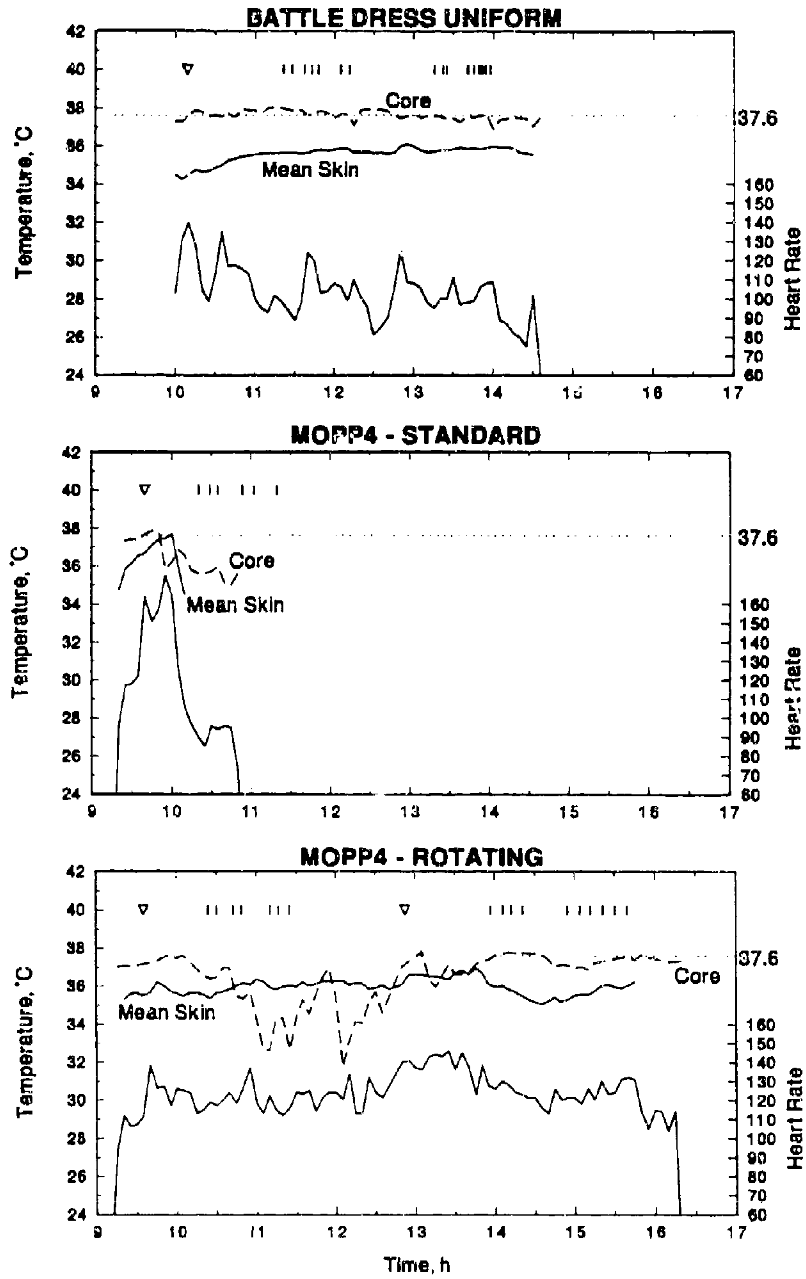
MOPP4 - STANDARD



MOPP4 - ROTATING

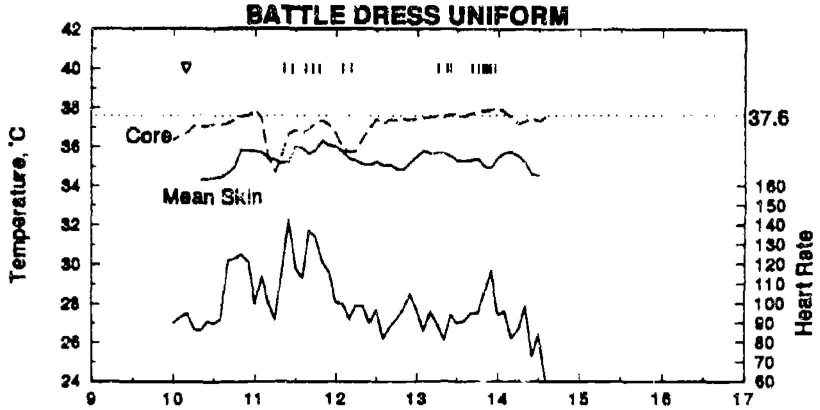


CREWMEMBER 21, GUNNER

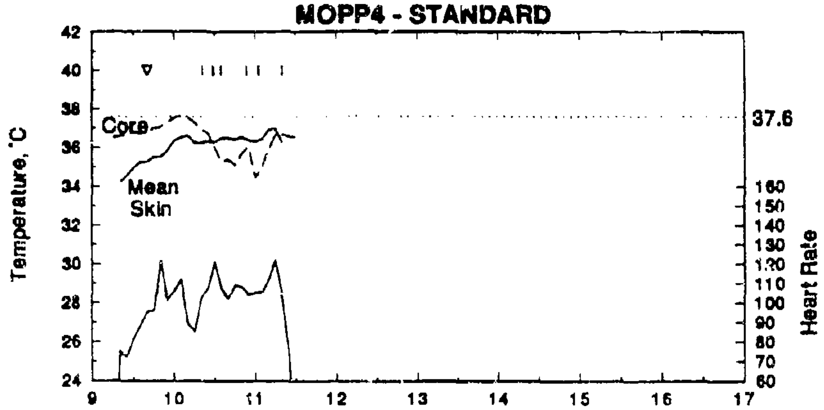


CREWMEMBER 22, ASSISTANT GUNNER

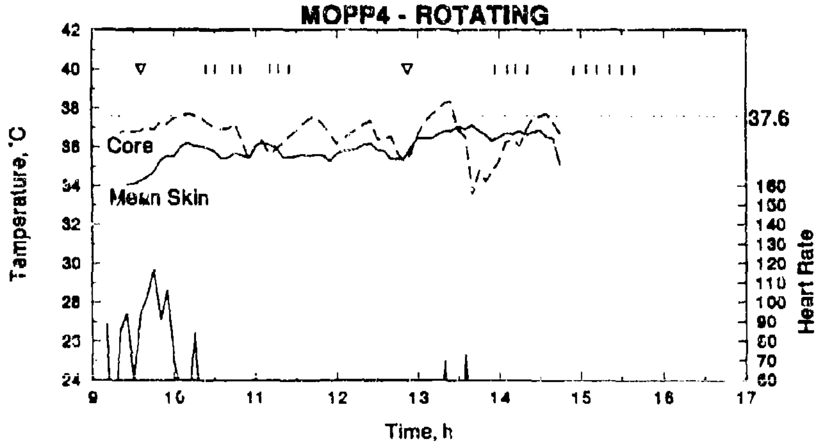
BATTLE DRESS UNIFORM

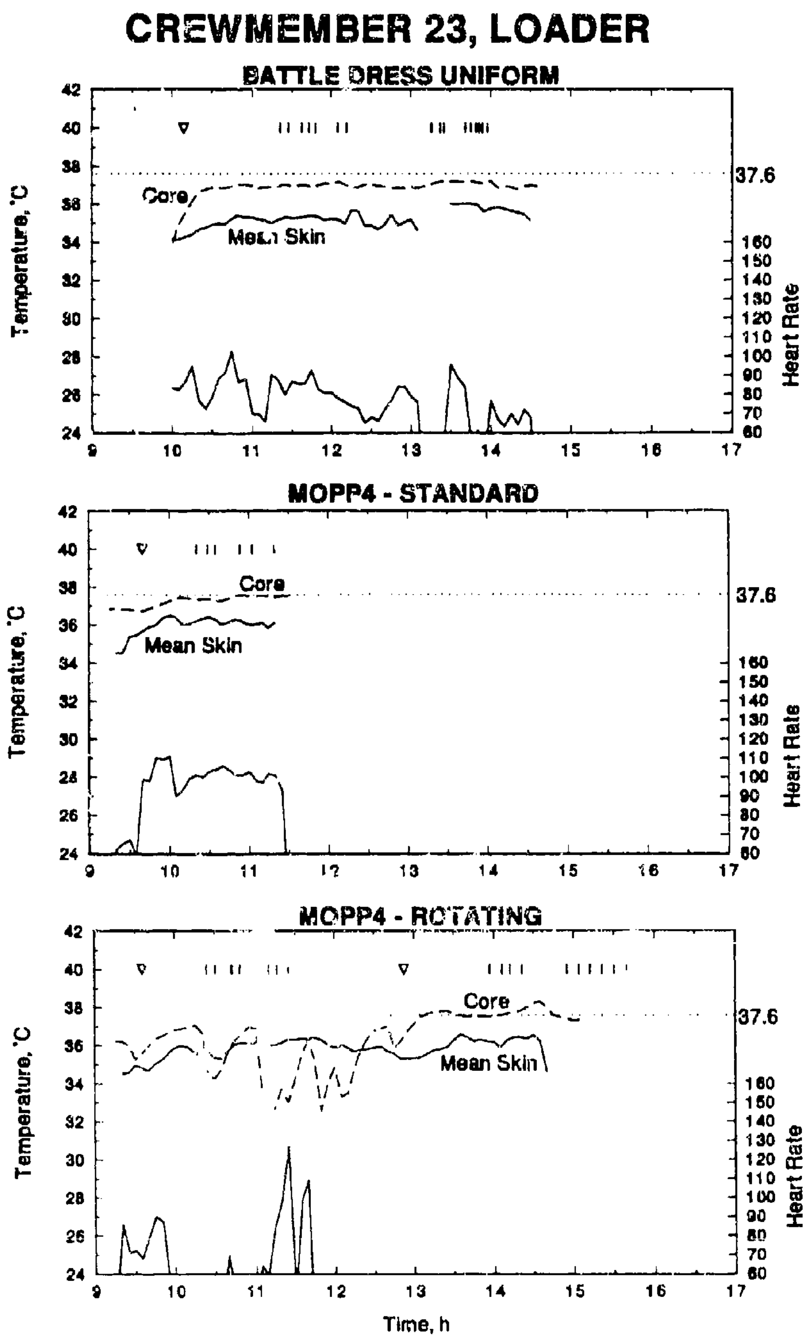


MOPP4 - STANDARD



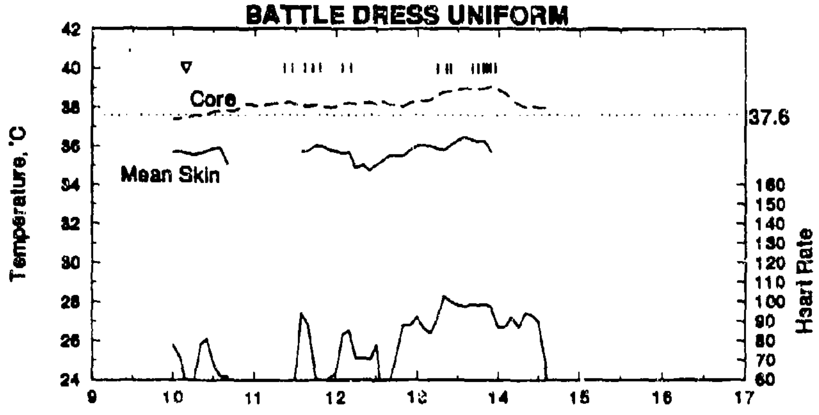
MOPP4 - ROTATING



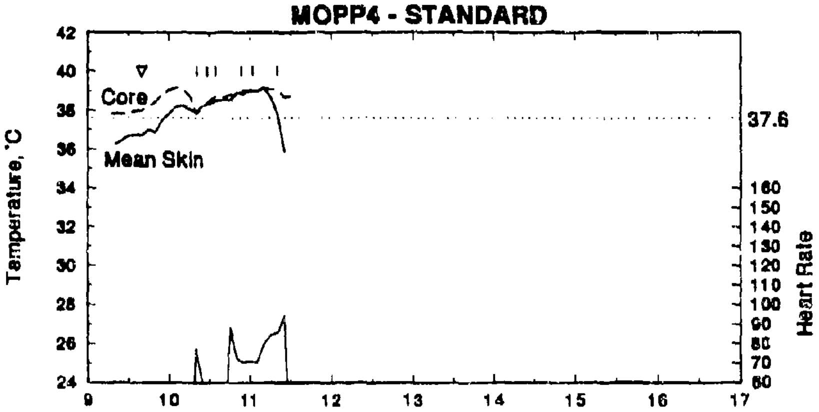

CREWMEMBER 23, LOADER
BATTLE DRESS UNIFORM
MOPP4 - STANDARD
MOPP4 - ROTATING
Core
Mean Skin
37.6
Temperature, °C
Heart Rate
Time, h

CREWMEMBER 24, #1 AMMO

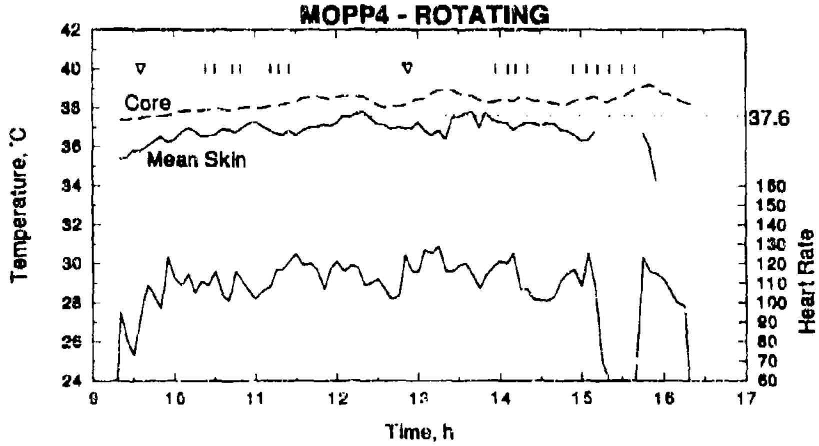
BATTLE DRESS UNIFORM



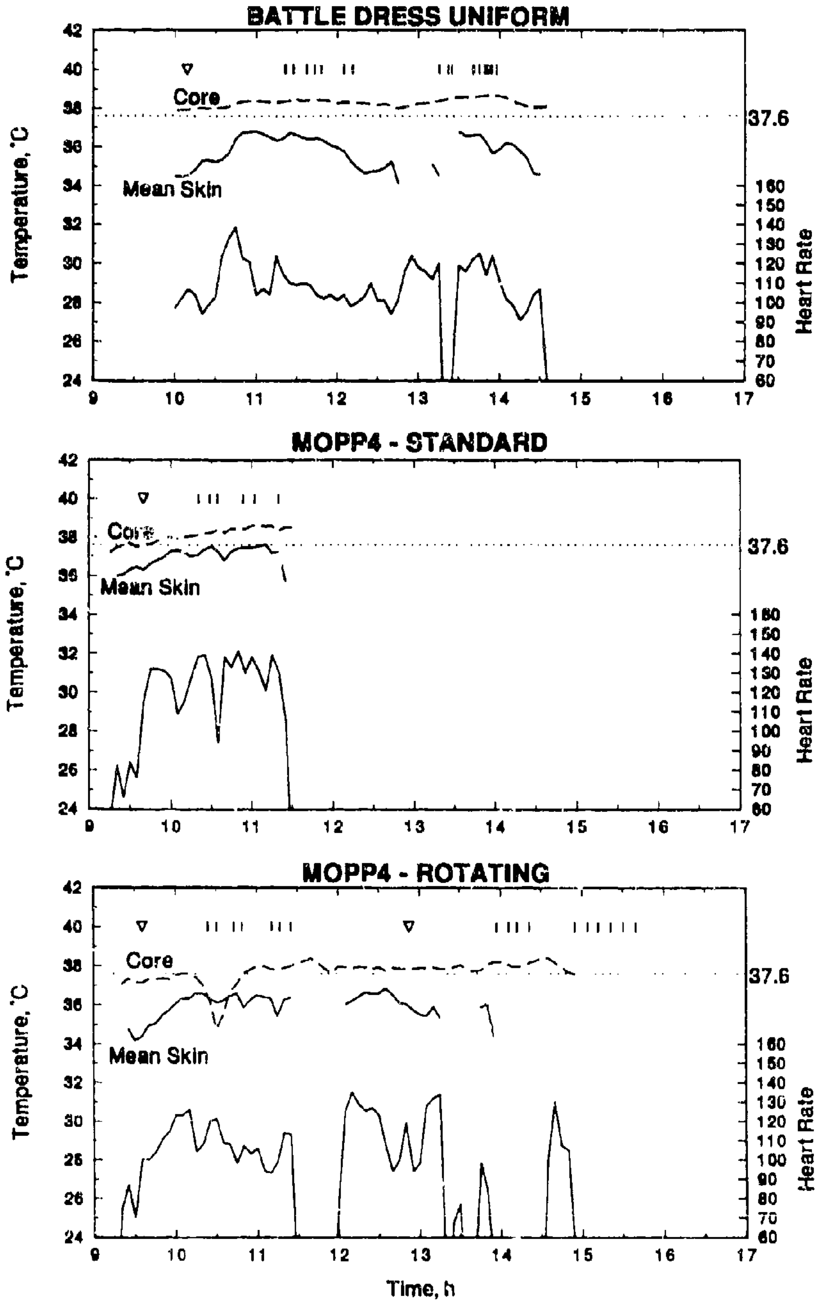
MOPP4 - STANDARD



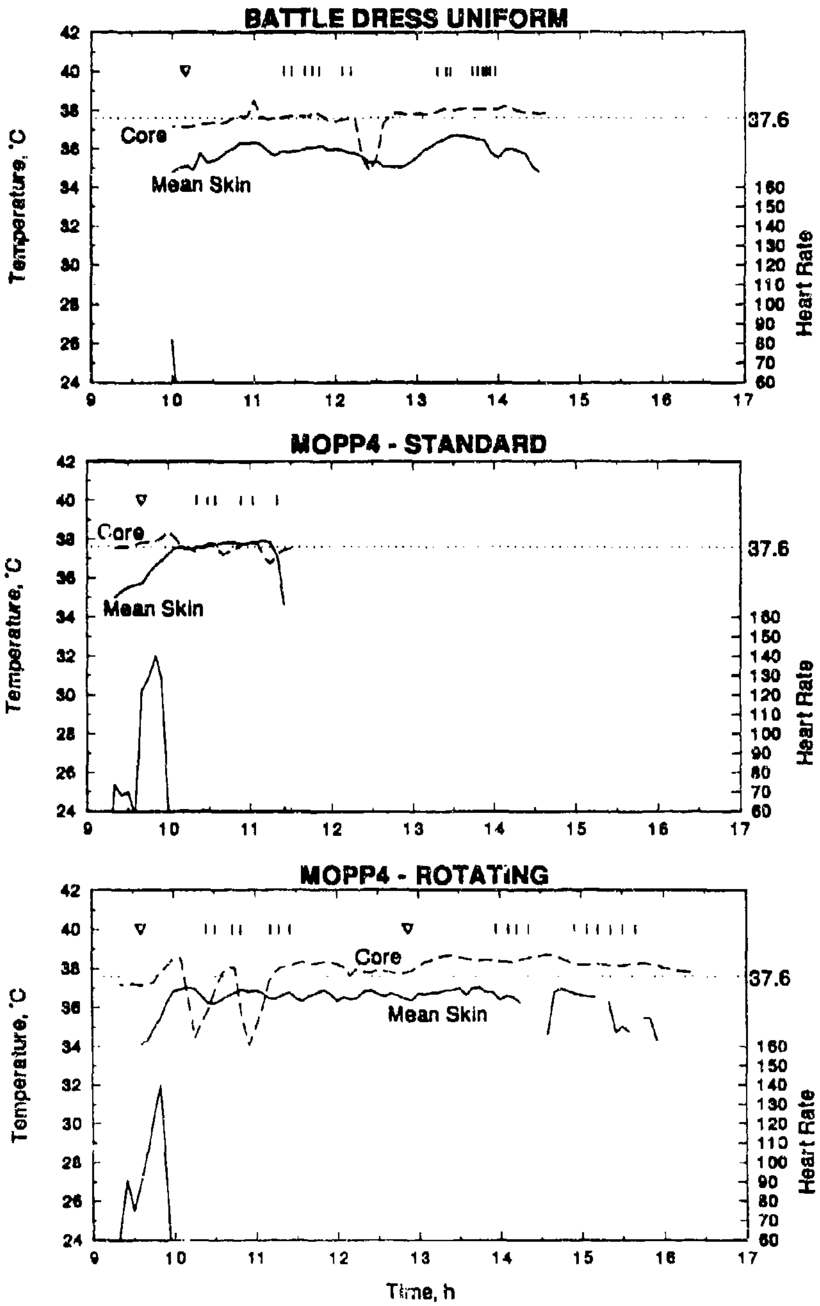
MOPP4 - ROTATING



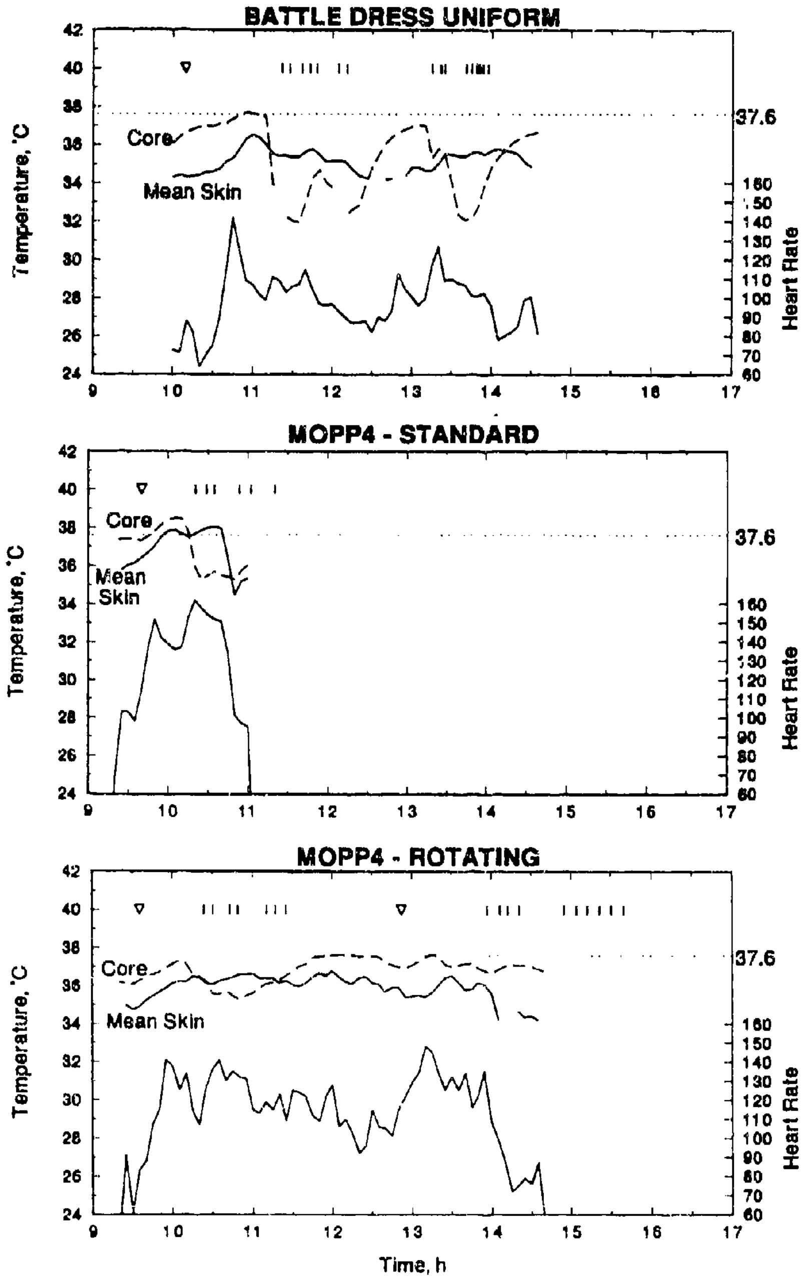
CREWMEMBER 25, #2 AMMO



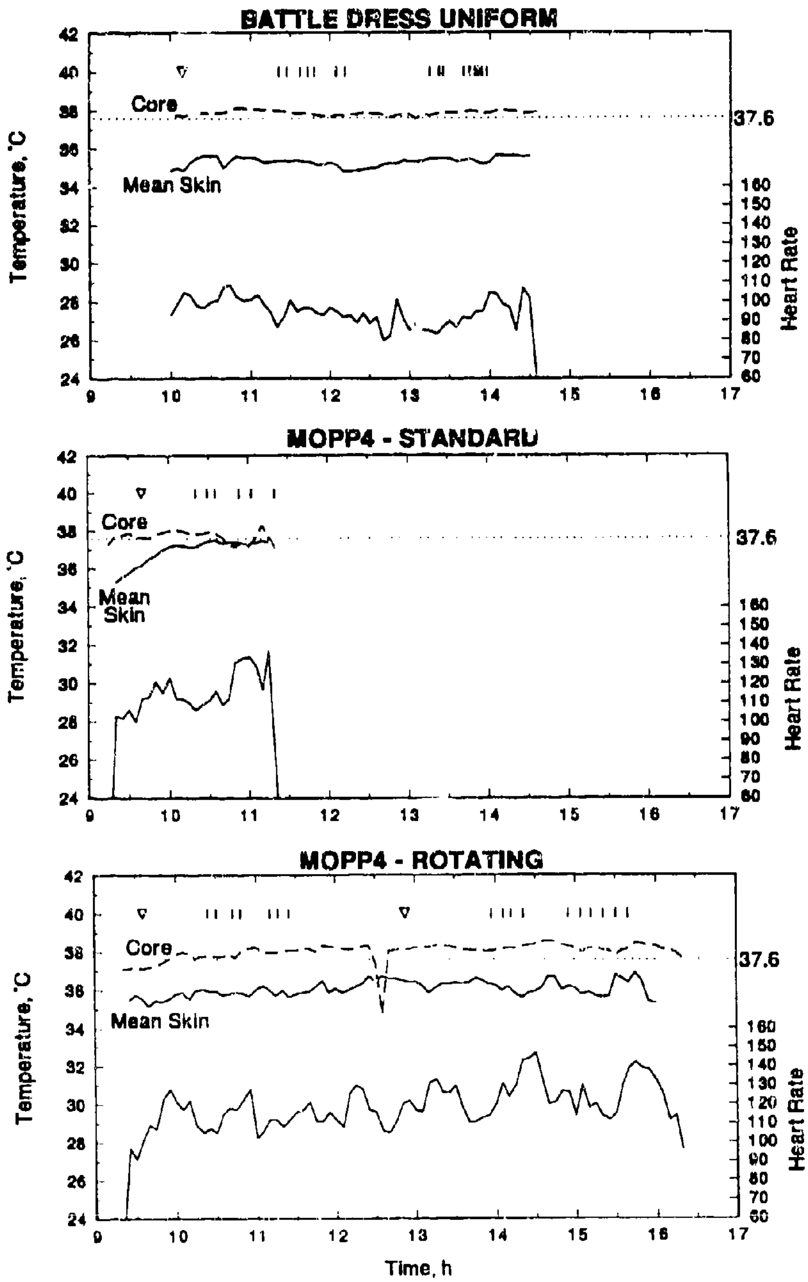
CREWMEMBER 26, #1 POWDER



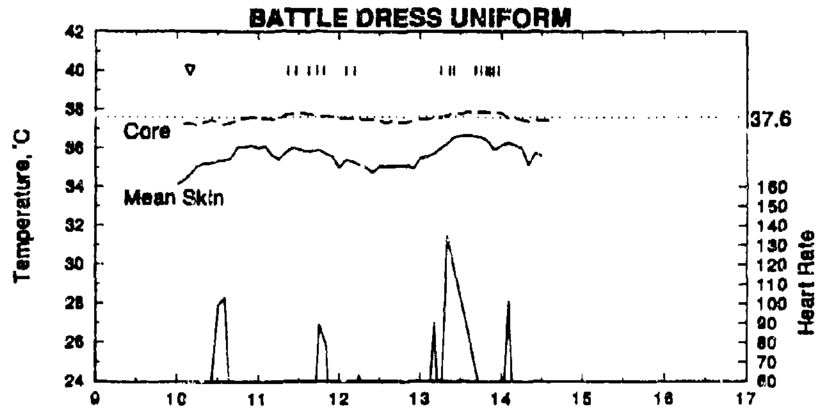
CREWMEMBER 27, #2 POWDER

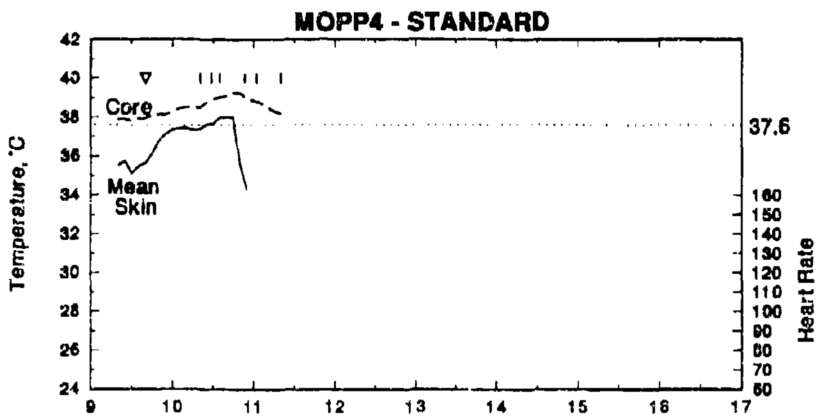


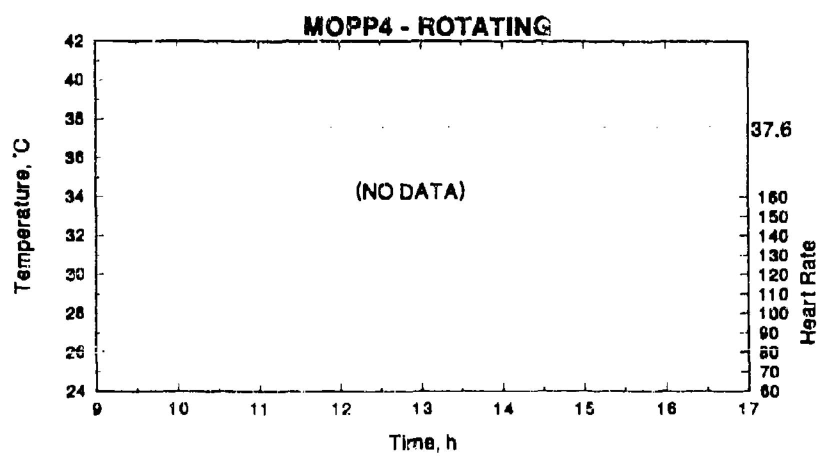
CREWMEMBER 28, RTO



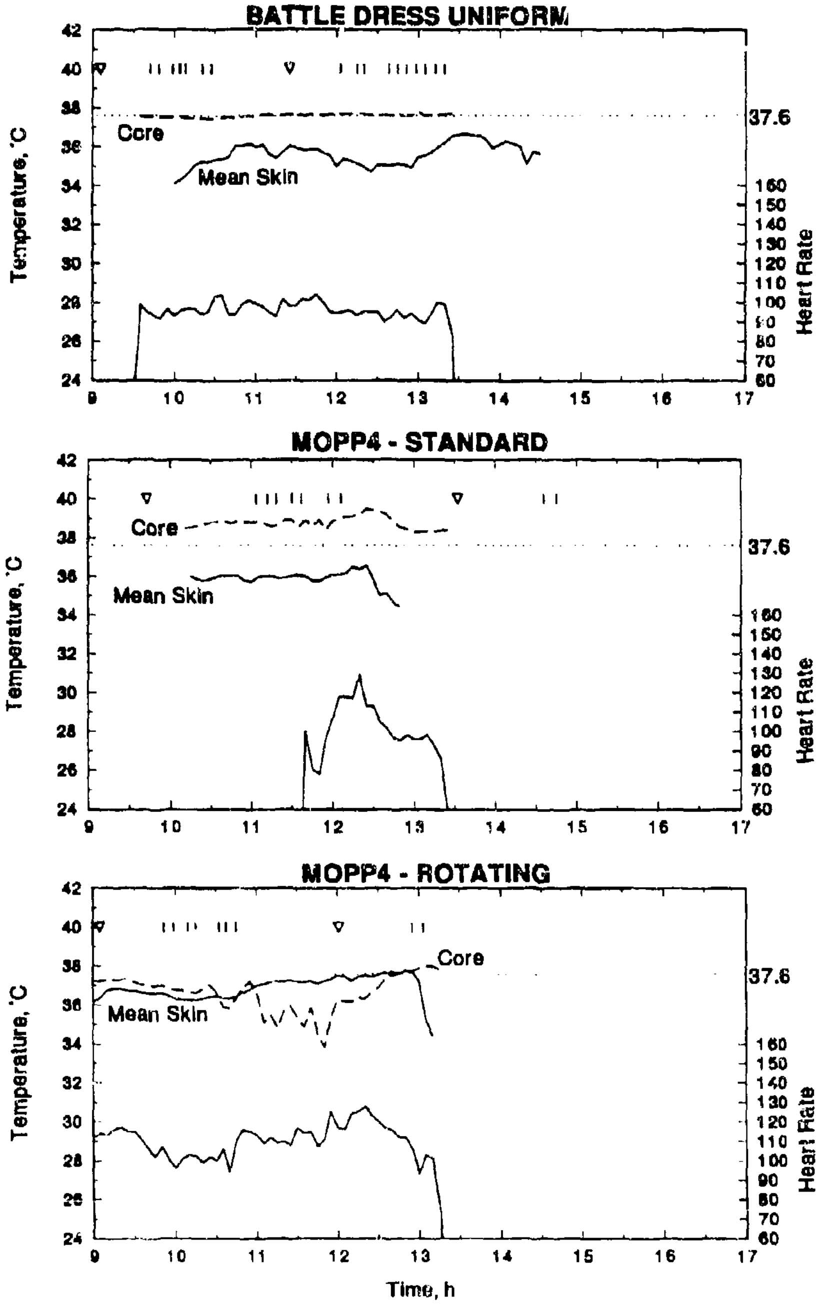
CREWMEMBER 29, DRIVER



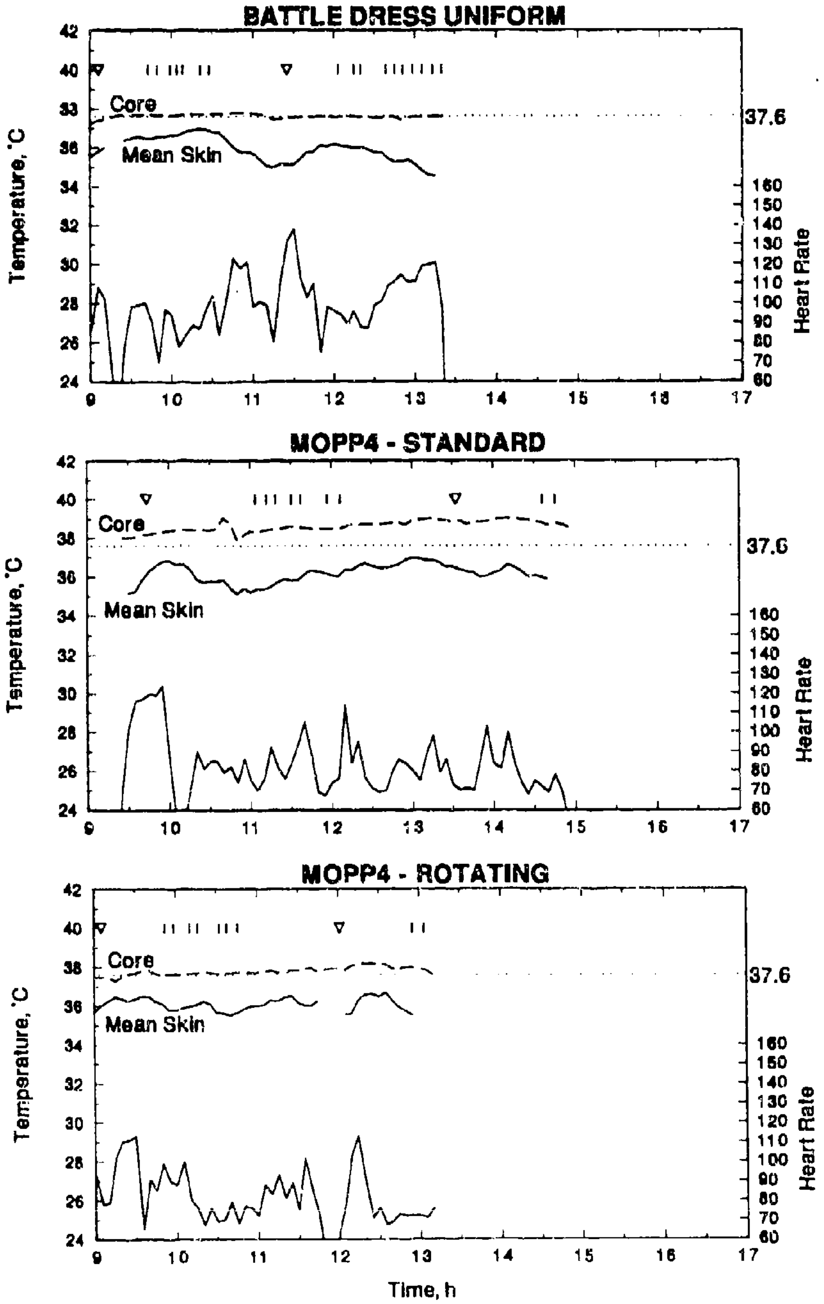




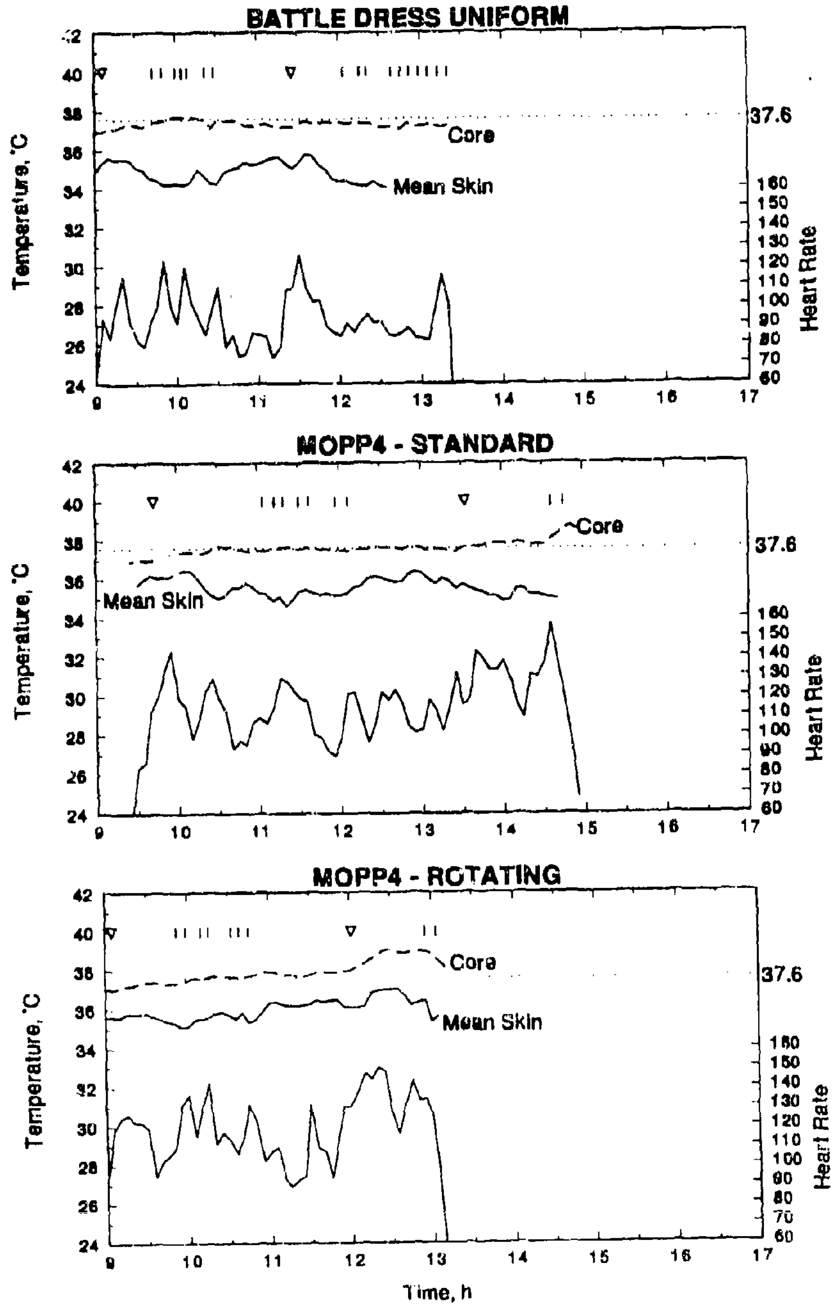
CREWMEMBER 30, CHIEF OF SECTION



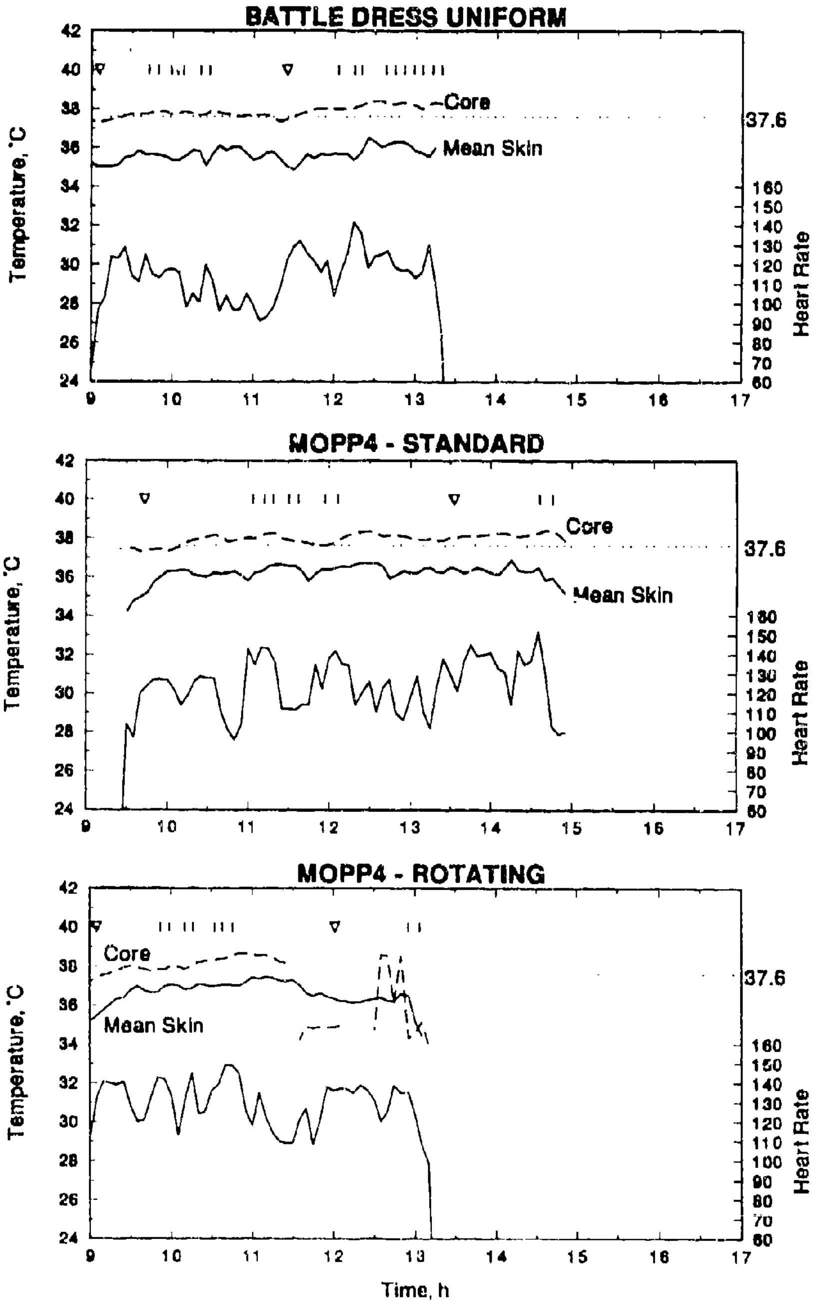
CREWMEMBER 31, GUNNER



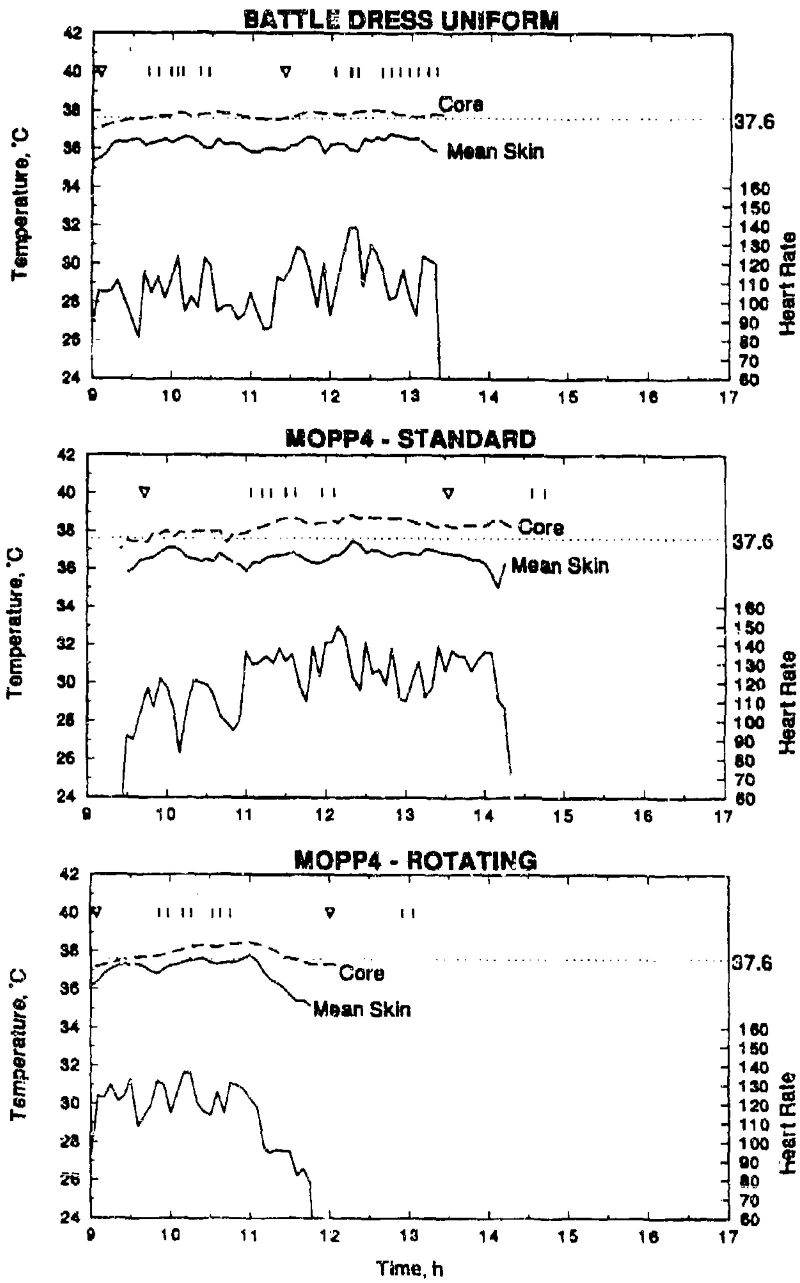
CREWMEMBER 32, ASSISTANT GUNNER



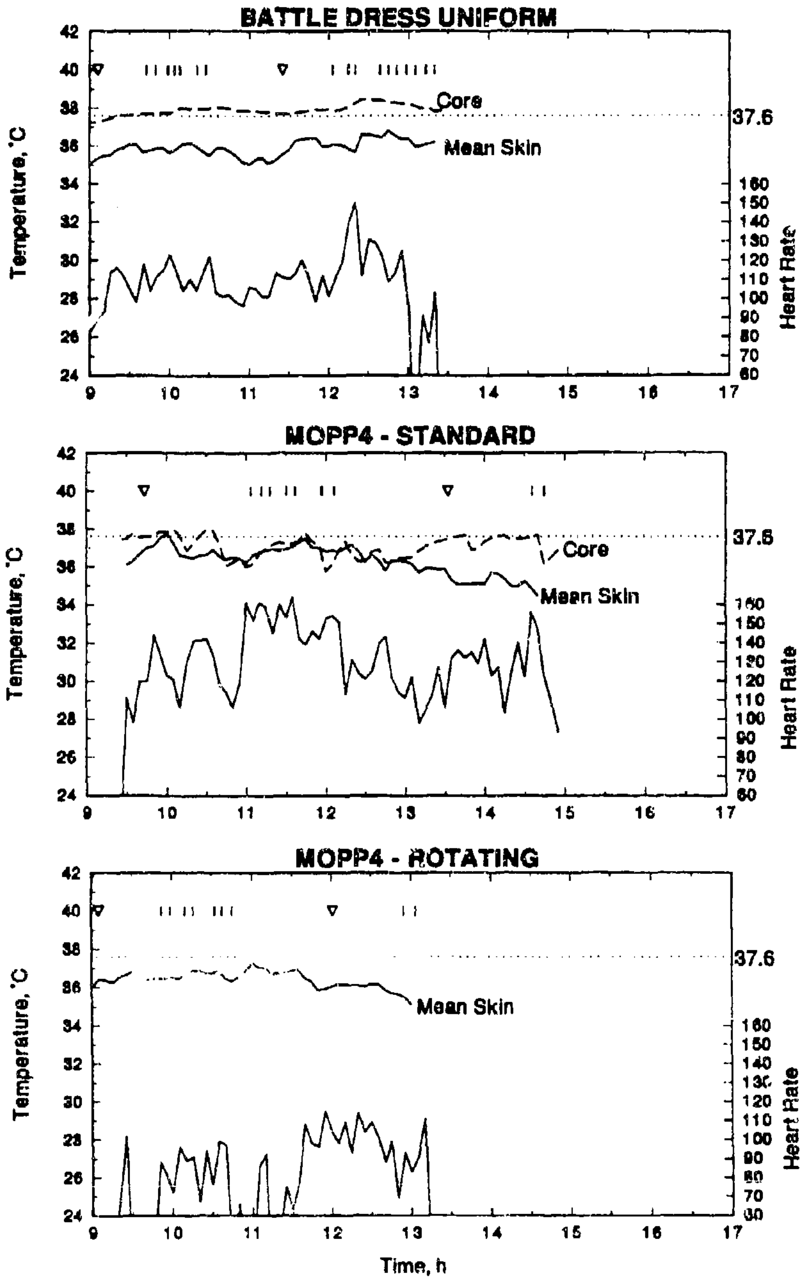
CREWMEMBER 33, LOADER



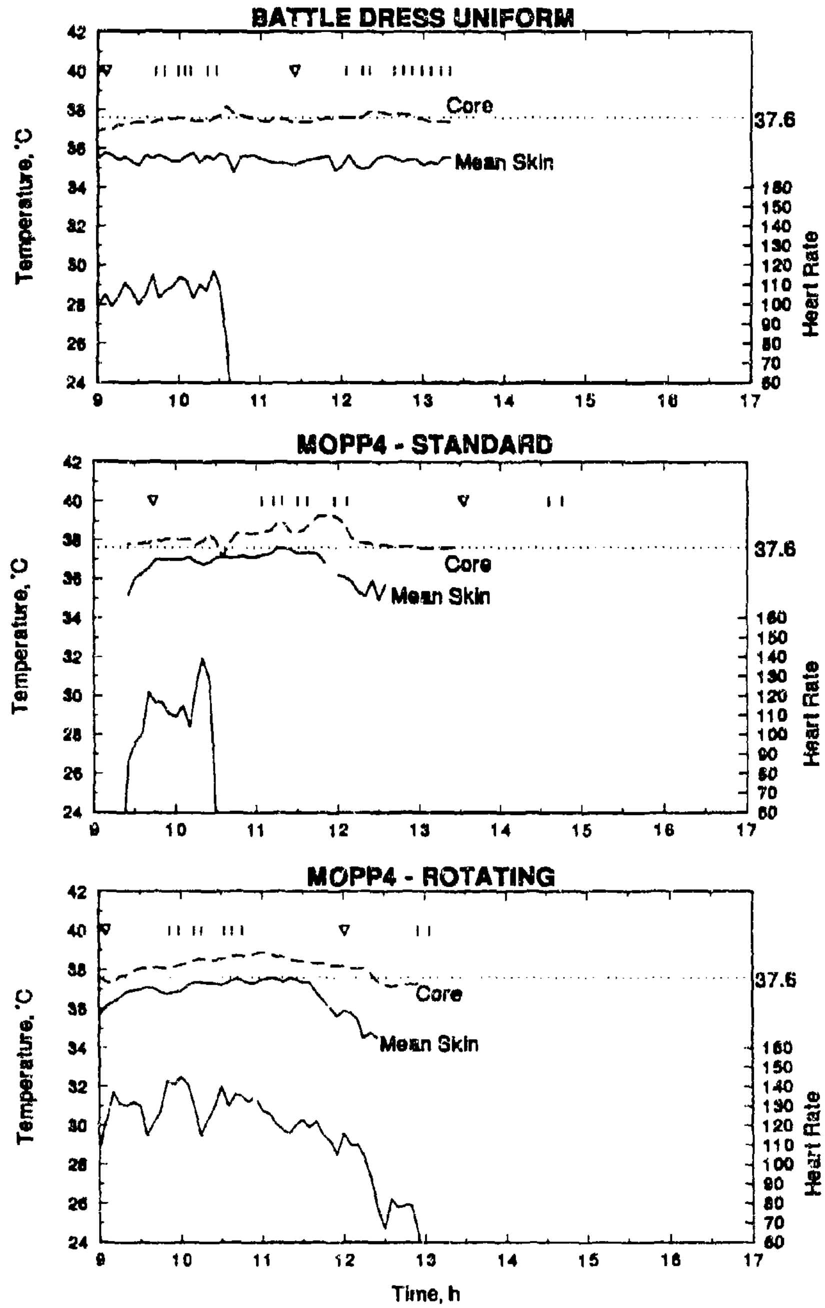
CREWMEMBER 34, #1 AMMO



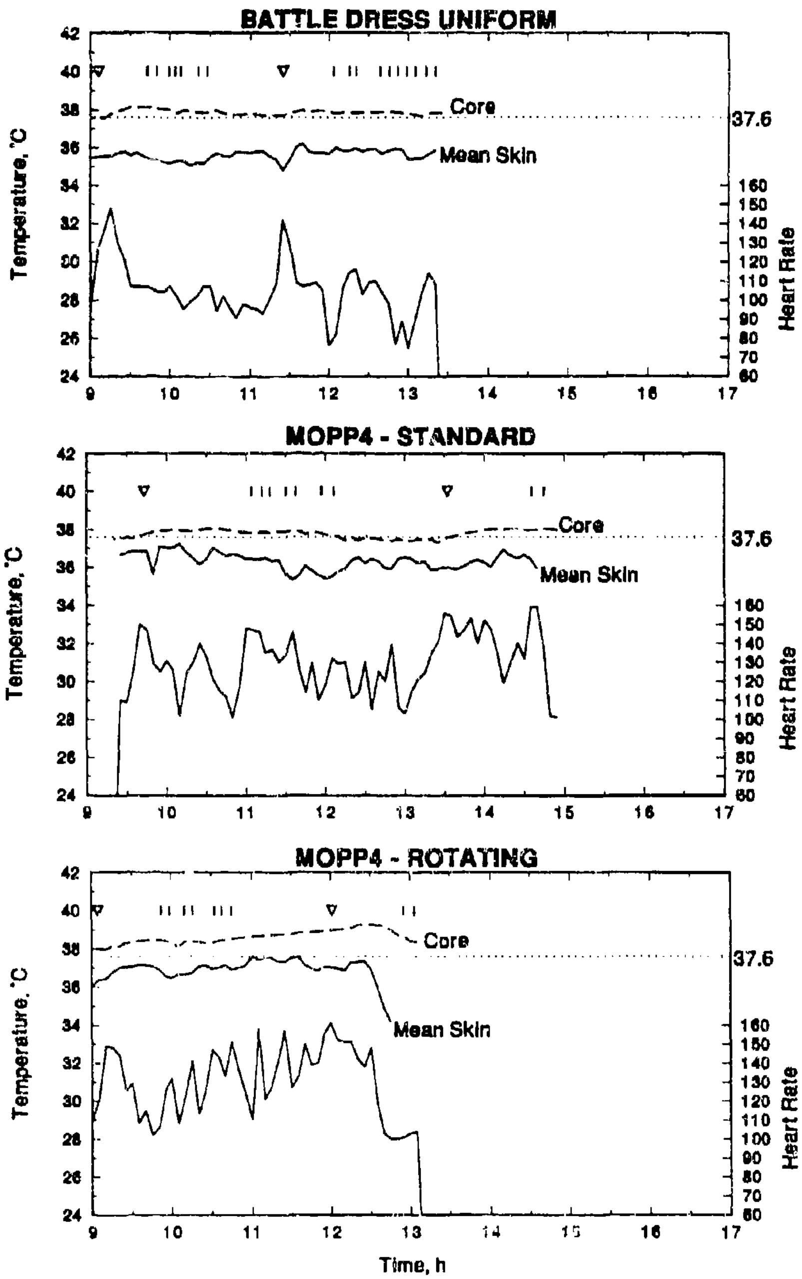
CREWMEMBER 35, #2 AMMO



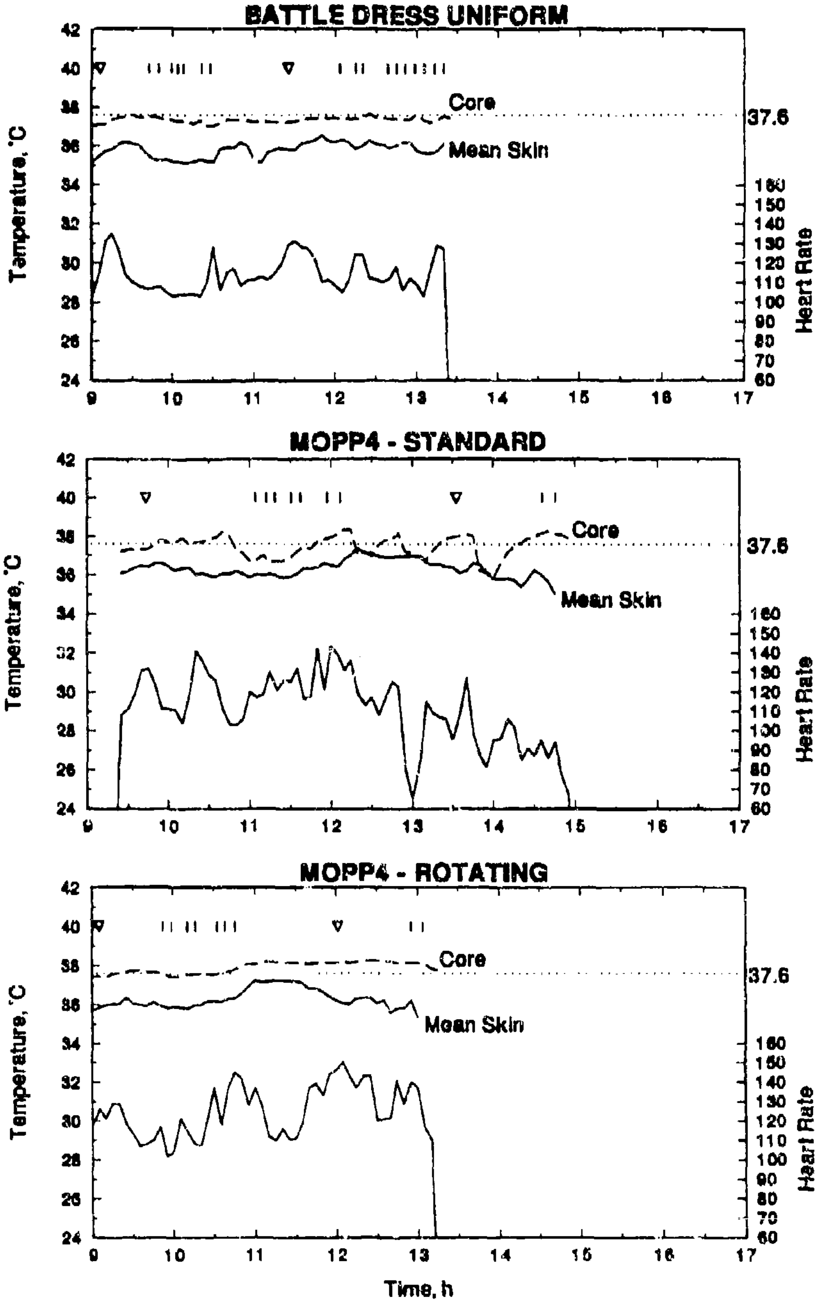
CREWMEMBER 36, #1 POWDER



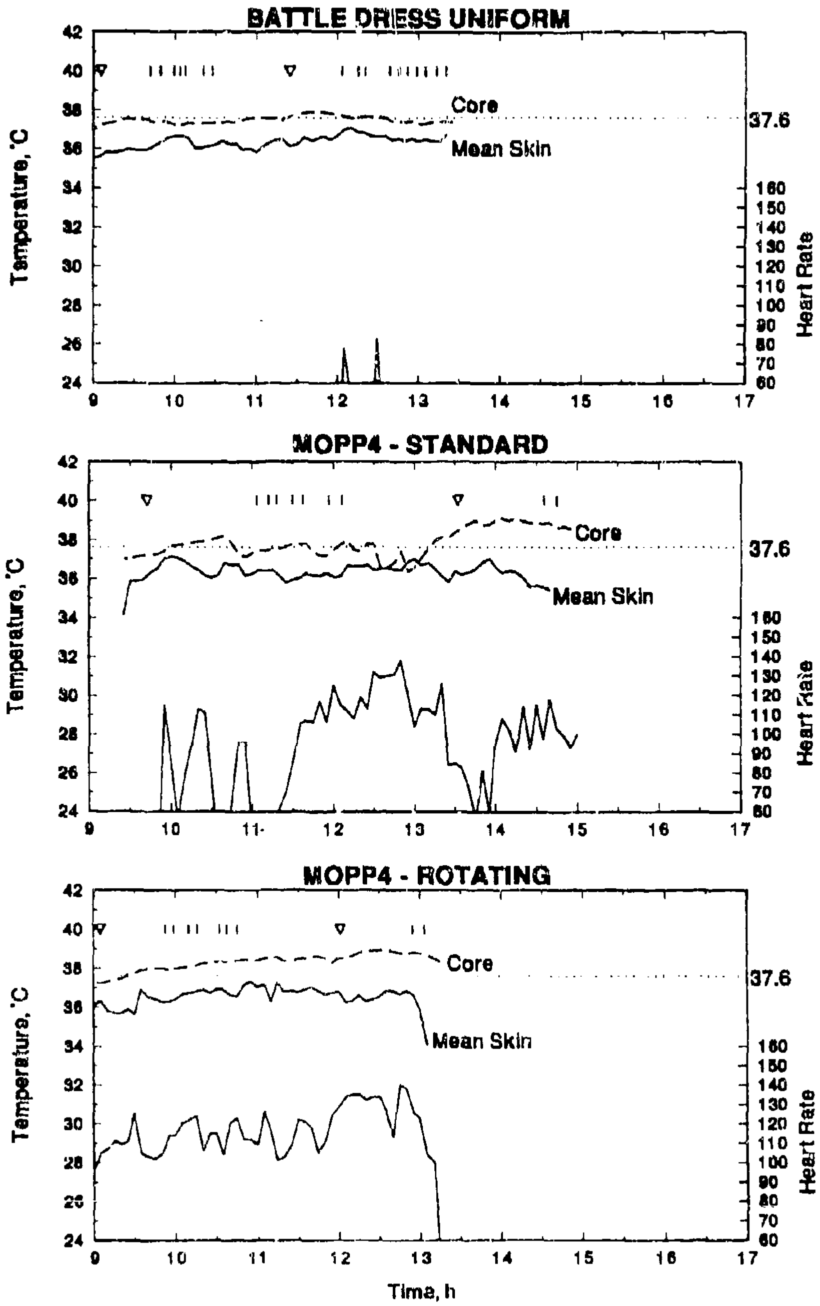
CREWMEMBER 37, #2 POWDER



CREWMEMBER 38, RTO



CREWMEMBER 39, DRIVER



DISTRIBUTION LIST

DNA-TR-93-173-V2

DEPARTMENT OF DEFENSE

ARMED FORCES RADIOBIOLOGY RSCH INST
ATTN: DIRECTOR
ATTN: MRA
ATTN: SCIENTIFIC DIRECTOR
ATTN: TECHNICAL LIBRARY

DEFENSE INTELLIGENCE AGENCY
ATTN: DB-6B
ATTN: DB-6E

DEFENSE NUCLEAR AGENCY
2 CY ATTN: ISST
ATTN: OPO
ATTN: OPS
ATTN: WE C MCFARLAND
ATTN: WEL
5 CY ATTN: WEP

DEFENSE TECHNICAL INFORMATION CENTER
2 CY ATTN: DTIC/OCP

FIELD COMMAND DEFENSE NUCLEAR AGENCY
ATTN: FCTO
ATTN: TTV
2 CY ATTN: TTV 3416TH TTSQ

NATIONAL DEFENSE UNIVERSITY
ATTN: ICAF TECH LIB
ATTN: NWCLB-CR

OASD (C3I)
ATTN: USD/P

TECHNICAL RESOURCES CENTER
ATTN: JNGO

U S EUROPEAN COMMAND
ATTN: ECJ-3
ATTN: ECJ5-N
ATTN: ECJ5N

USSSTRATCOM/J531T
ATTN: J-521

DEPARTMENT OF THE ARMY

ARMY RESEARCH LABORATORIES
ATTN: TECH LIB

NUCLEAR EFFECTS DIVISION
ATTN: STEWS-NE-T

U S ARMY CHEMICAL SCHOOL
ATTN: CARL FRAKER

U S ARMY COMBAT SYSTEMS TEST ACTIVITY
ATTN: JOHN GERDES

U S ARMY COMD & GENERAL STAFF COLLEGE
ATTN: ATZL-SWJ-CA
ATTN: ATZL-SWT-A

U S ARMY CONCEPTS ANALYSIS AGENCY
ATTN: TECHNICAL LIBRARY

U S ARMY FIELD ARTILLERY SCHOOL
ATTN: ATSF-CD

U S ARMY NATIONAL GROUND INTELLIGENCE CTR
ATTN: C WARD

U S ARMY NUCLEAR & CHEMICAL AGENCY
4 CY ATTN: MONA-NU DR D BASH
ATTN: MONA-NU LTC BLISS

U S ARMY RESEARCH LAB
ATTN: AMSRL-SL-B DR KLOPCIC
ATTN: AMSRL-SL-BS E DAVIS
ATTN: SLCBR-D
ATTN: SLCBR-DD-T
ATTN: SLCBR-TB

U S ARMY RESEARCH LABORATORY
ATTN: DIRECTOR
ATTN: DR D HODGE

U S ARMY TEST & EVALUATION COMMAND
ATTN: STECS-NE

U S ARMY VULNERABILITY/LETHALITY
ATTN: AMSLC-VL-NE DR J FEENEY

U S ARMY WAR COLLEGE
ATTN: LIBRARY

U S MILITARY ACADEMY
ATTN: BEHAVORIAL SCI & LEADERSHIP

U S ARMY MEDICAL RESEARCH & DEVELOPMENT COMMAND
ATTN: SGRD-PLE

US ARMY MODEL IMPROVEMENT STUDY MANAGEMENT AGENCY
ATTN: E VISCO

DEPARTMENT OF THE NAVY

MARINE CORPS
ATTN: CODE PPO
ATTN: PSI G RASP

NAVAL WAR COLLEGE
ATTN: DOCUMENT CONTROL
ATTN: LIBRARY

NUCLEAR WEAPONS TNG GROUP, ATLANTIC
ATTN: CODE 222

OFFICE OF CHIEF NAVAL OPERATIONS
ATTN: N 51
ATTN: NIS-22
ATTN: NOP 603
ATTN: NOP 91
ATTN: N455

OPERATIONAL TEST & EVALUATION FORCE
ATTN: COMMANDER

PLANS, POLICY & OPERATIONS
ATTN: CODE-P
ATTN: CODE-POC-30

DEPARTMENT OF THE AIR FORCE

AIR UNIVERSITY LIBRARY
ATTN: LIBRARY

ARMSTRONG LABORATORY
ATTN: AL/CFBE DR F S KNOX

ASSISTANT CHIEF OF STAFF
ATTN: AFSAA/SAMI

DEPUTY CHIEF OF STAFF FOR PLANS & OPERS
ATTN: AFXOOSS

HQ ACC/XP-JSG
ATTN: ACC/XP-JSG

HQ USAFA/DFSELD
ATTN: LIBRARY

DEPARTMENT OF ENERGY

DEPARTMENT OF ENERGY
ATTN: DR T JONES

LAWRENCE LIVERMORE NATIONAL LAB
ATTN: A WARSHAWSKY
ATTN: Z DIVISION LIBRARY

OTHER GOVERNMENT

CENTRAL INTELLIGENCE AGENCY
ATTN: NIO-T
ATTN: N10 STRATEGIC SYS

FEDERAL EMERGENCY MANAGEMENT AGENCY
ATTN: NP-CP
ATTN: OFC OF CIVIL DEFENSE

U S NUCLEAR REGULATORY COMMISSION
ATTN: S YANIV

DEPARTMENT OF DEFENSE CONTRACTORS

ARES CORP
ATTN: A DEVERILL
ATTN: A J BARKLEY
ATTN: G E MCCLELLAN
ATTN: G H ANNO
ATTN: J T ROTH
ATTN: L N MATHESON

HORIZONS TECHNOLOGY INC
ATTN: F GREY

INSTITUTE FOR DEFENSE ANALYSES
ATTN: DOUGLAS SCHULTZ
ATTN: M FINEBERG

JAYCOR
ATTN: CYRUS P KNOWLES

KAMAN SCIENCES CORPORATION
ATTN: DASIAC

LOGICON R & D ASSOCIATES
ATTN: DOCUMENT CONTROL

MICRO ANALYSIS AND DESIGN
ATTN: N LAVINE
ATTN: R LAUGHERY
ATTN: T ROTH

PACIFIC-SIERRA RESEARCH CORP
2 CY ATTN: G ANNO
ATTN: H BRODE

PACIFIC-SIERRA RESEARCH CORP
ATTN: D GORMLEY
2 CY ATTN: G MCCLELLAN

SCIENCE APPLICATIONS INTL CORP
ATTN: D KAUL
ATTN: E SWICK
ATTN: W WOOLSON

SCIENCE APPLICATIONS INTL CORP
ATTN: J MCGAHAN